SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Mechanics of Aeration—Pasveer

Enzymes and Digestion—Heukelekian and Berger

Floatable Oil Determination—Pomeroy

Pressure Flotation for Soluble Oils—Beebe

San Diego Outfall Studies—Kersnar and Caldwell

NOVEMBER, 1953—VOL. 25, No. 11

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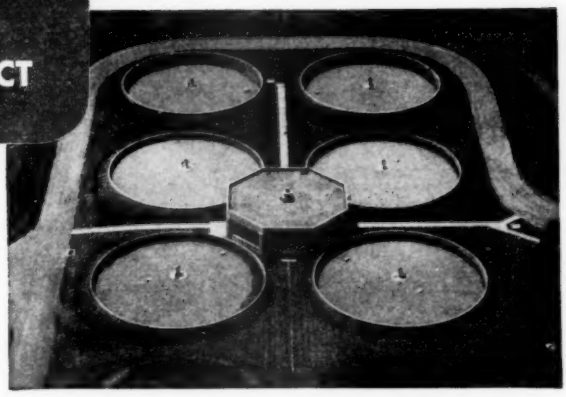
Please remit directly to your Member Association Secretary immediately upon receipt of the first dues notice from him.

ACCELERATED SLUDGE DIGESTION NOW A FACT

*Exclusively through the Catalytic Reduction Process**



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The Catalytic Reduction Process completes biological sludge digestion in one-third to one-fourth of digester volume generally required. The Process accomplishes this by digesting at solids loading rates three to four times those being practiced. This accelerated digestion is simple and economical, using only the natural products of anaerobic decomposition.

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SEWAGE AND INDUSTRIAL WASTES

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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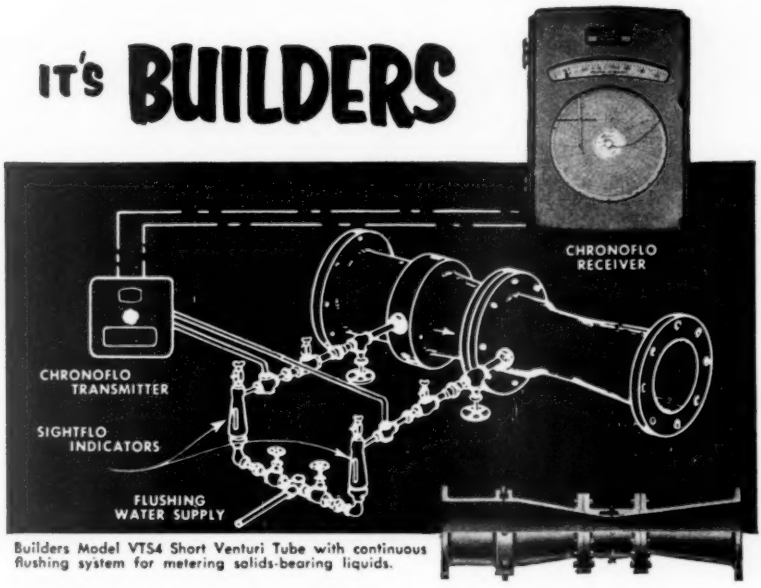

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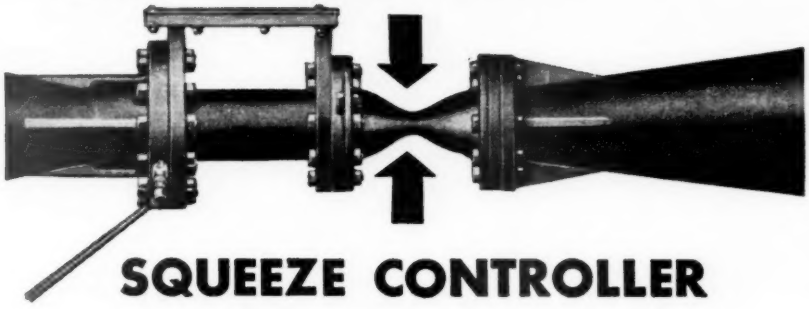

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Look at these advantages. A Simplex venturi tube, the most accurate form of primary device, does double duty, measures as it controls. The throat section is self-scouring. Viscous fluids contact no moving parts.

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MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Oklahoma Water, Sewage and Industrial Wastes Conference	Okla. A & M College, Stillwater, Okla.	Nov. 16–20, 1953
New York Sewage and Industrial Wastes Assn.	Belmont Plaza, New York City, N. Y.	Jan. 21–22, 1954
New Jersey Sewage and Industrial Wastes Assn.	The Traymore Hotel, Atlantic City, N. J.	March 10–12, 1954
Arkansas Water and Sewage Conference	Hotel Marion, Little Rock, Ark.	March 22–24, 1954
Kansas Sewage Works Assn.	Broadview Hotel, Emporia, Kan.	April 7–9, 1954
Arizona Sewage and Water Works Assn.	Santa Rita Hotel, Tuscon, Ariz.	April 22–24, 1954
Montana Sewage and Industrial Wastes Assn.	Hotel Baxter, Bozeman, Mont.	April 22, 1954
Maryland-Delaware Water and Sewage Assn.	Hotel Francis Scott Key, Frederick, Md.	April 29–30, 1954
California Sewage and Industrial Assn.	Hotel Senator, Sacramento, Calif.	May 5–8, 1954
Central States Sewage and Industrial Wastes Assn.	Hotel Leland, Richmond, Ind.	June 24–26, 1954
Pennsylvania Sewage and Industrial Wastes Assn.	The Pennsylvania State College, State College, Pa.	Aug. 25–27, 1954
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Andrew Jackson Hotel, Nashville, Tenn.	Sept. 20–22, 1954

TWENTY-SEVENTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations

in conjunction with

Ohio Sewage and Industrial Wastes Treatment Conference
Netherland Plaza Hotel, Cincinnati, Ohio

October 11–14, 1954

Briefs from the YEOMANS GUARD

Across the board— WIN, PLACE, and SHOW: the Treatment Plant at Tupelo

Take an appreciative look at these figures:

Daily flow	0.999 MGD
Raw sewage B.O.D.	286 ppm
Raw Sewage, suspended solids	216 ppm
Final effluent B.O.D.	31 ppm
Final effluent, suspended solids	34 ppm
Overall reduction B.O.D.	89%
Overall reduction, suspended solids	84%

These are average figures, reported from August '52 to January '53, inclusive, of operating results at the treatment plant in Tupelo, Mississippi.

It's a Yeomans plant—consists of a primary Spiraflo Clarifier, an Aero Filter Distributor and final Spiraflo Clarifier; plus a full quota of necessary pumps. It handles industrial wastes and domestic.

Simplicity of operation was a prime requisite; and the plant operates automatically with electrical control.

Further, its high efficiency is matched by its exceptional economy.

Still more, it's a sightly plant—bespeaks an alert, heads-up well managed community.

A full report covering plant details and performance data on request.

☐ Please send Tupelo report.

Four Aero-Filters Purify Domestic and Industrial Wastes at Rochester, Minn.

That standard type units lend themselves to special combinations for off-standard needs is well demonstrated by the sewage treatment plant at Rochester, Minnesota.

A strong probability that wastes from milk-processing plants, present in the sewage, would quickly become septic made it necessary to short-cut standard purifying procedure in order to hasten oxidation. For that reason basic treatment by rotary screens instead of conventional settling tanks delivers the sewage in the shortest possible time to four Yeomans high capacity Aero-Filters.

By this means oxidative purification is started much sooner, and the filter's work is made much easier.

With a complete line of standard units of every type—activated sludge process or high-capacity trickling filters—Yeomans engineers can assist in designing a plant custom-fitted to meet special requirements: a unique advantage.

Good business—consult Yeomans.

Centrifugal Pump or Pneumatic Ejector—Yeomans Can Recommend Either

When you submit to Yeomans any problem of handling material by pumping it, you can be entirely sure that you'll get an unbiased recommendation—as to centrifugal pump or pneumatic ejector.

> Yeomans engineering attention focuses on the character of material to be pumped and on other technical aspects of the job to be done—in order to determine which type of equipment will perform most efficiently, dependably and at lowest cost.

This claim of objectivity is, to be sure, common to practically all equipment manufacturers; but here it has added significance because Yeomans builds both centrifugals and pneumatics.

In all other respects a Yeomans recommendation is enthusiastically biased—because we are utterly convinced that Yeomans Pumps—either centrifugals or pneumatics are the best pumps built.

The Yeomans Guard, published several times a year, is a compendium of news and useful information covering the pumping of materials and the treatment of wastes, both domestic and industrial. We shall be pleased to send you the current issue if you'd care to have it. Ask your local Yeomans Representative—listed in the telephone book yellow pages under "Pumps"—or write direct.

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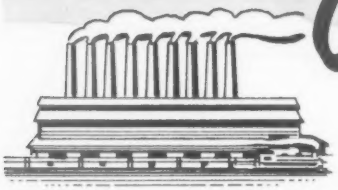
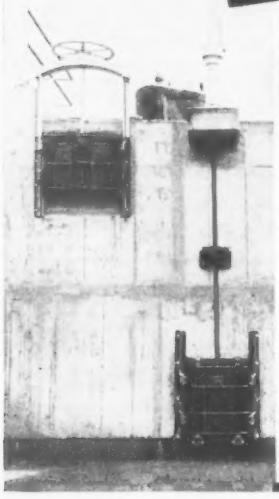
Manufacturers of: Centrifugal Pumps and Pneumatic Ejectors for Buildings, Municipalities, and Industrial Applications, and a Full Line of Waste Treatment Equipment.

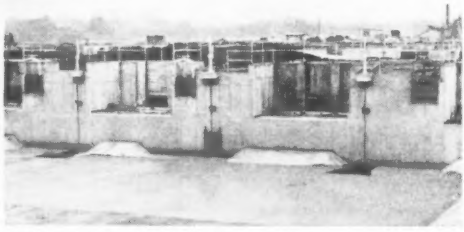
Pekrul Gates



All sluice gates installed in the **United States Steel Corporation's** huge, new Fairless Works, Fairless Hills, Pa., were designed and manufactured by PEKRUL. Shown here are several gates among approximately 200 PEKRUL gates installed in pump stations and sedimentation basins.

Put PEKRUL to Work for You!





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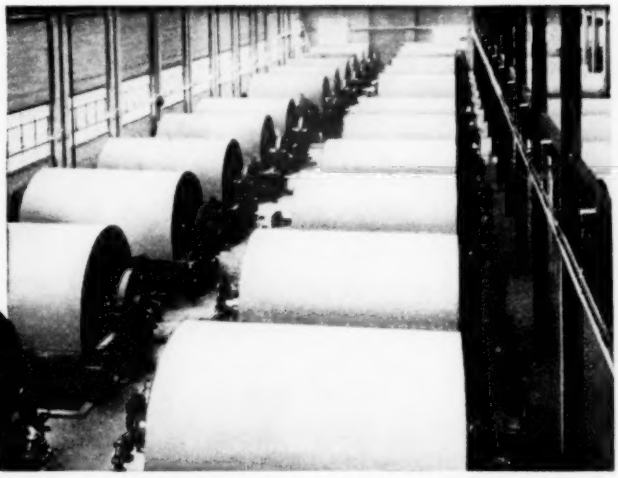

Designed to do your job best!

66 Conkey Sludge Filters now installed in one plant of Chicago Sanitary District

The West-Southwest Treatment Works of the Chicago Sanitary District is the largest sewage treatment plant in the world. Here, the huge volume of industrial and residential waste from the heavily populated metropolitan area has presented sewage engineers with an unparalleled challenge. Progressively, the Chicago Sanitary District has met that challenge. Starting twenty years ago with installations of continuous vacuum filters for activated sludge, Sanitary District engineers have developed the most exacting specifications and rigid requirements for filter designs and performance . . . culminating in the installation of 66 Conkey Rotary Drum Vacuum Filters for this largest single installation in the sewage field.

These Conkey units incorporate:

Polystyrene plastic cloth backing drainage plates for long cloth life and low maintenance.

Floating cake discharge scraper.

Protective coatings for filter components.

—and other superior design and constructive features.

For equivalent Conkey design and fabrication for your filter installation, write General American. Ask for bulletin No. 100 or for a consultation with one of our engineers.

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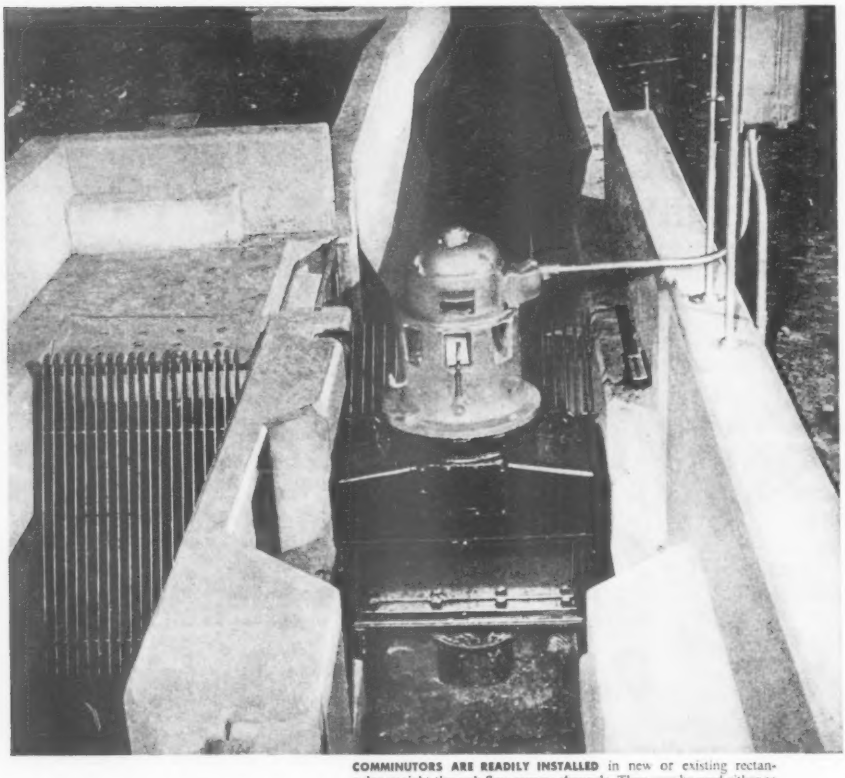

COMMINUTORS ARE READILY INSTALLED in new or existing rectangular straight-through flow sewage channels. They may be used either as single units shown above or multiple units, depending on your needs.

Worthington comminutors eliminate costly handling of sewage solids

With a Worthington comminutor operating continuously, you can forget about raking, hauling, grinding, and burial or incineration of coarse solids. Here's why:

Worthington comminutors *automatically* cut coarse solids in raw sewage so rapidly that loss of head is minimized. Peak loads in excess of comminutor capacity are easily handled by a baffle screen. The addition of a mercury seal keeps all working parts watertight for continuous operation even when comminutor itself is submerged.

Quick, simple installation in either new or existing rectangular sewage channels, indoors or outside, keeps costs to a minimum. Stainless steel screens and cutters are easy to remove for inspection, adjustment, sharpening or replacement.

Worthington engineers will be glad to help you mechanize and modernize this or any other phase of your sewage treatment. Write for full details on Worthington's complete line of sewage disposal equipment. Worthington Corporation, Public Works Division, Section W.3.3, Harrison, N. J.

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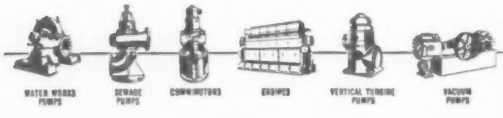

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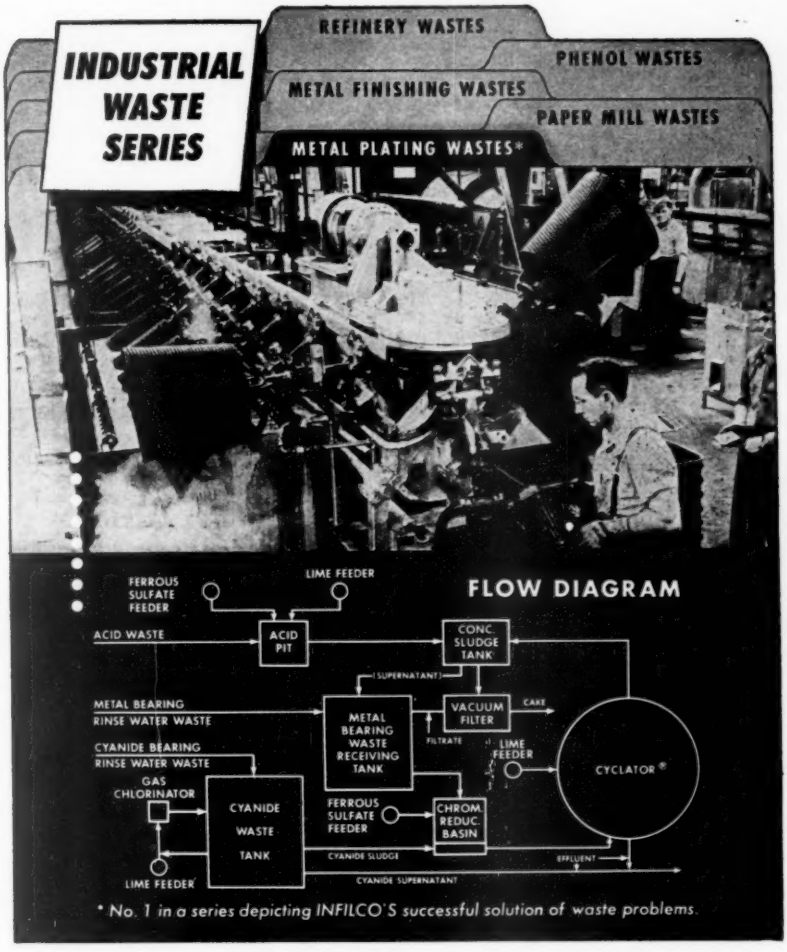


There is no "cure all" for solving waste treatment problems.

FOR EXAMPLE: our thorough evaluation of your problem could dictate the utilization of ion exchange rather than the precipitation equipment found most practical in the existing plating waste installation diagrammed above.

We invite your specific inquiries and know that our wide experience in all phases of waste treatment will prove helpful to you. Request Bulletin 70-S and W-800-S.

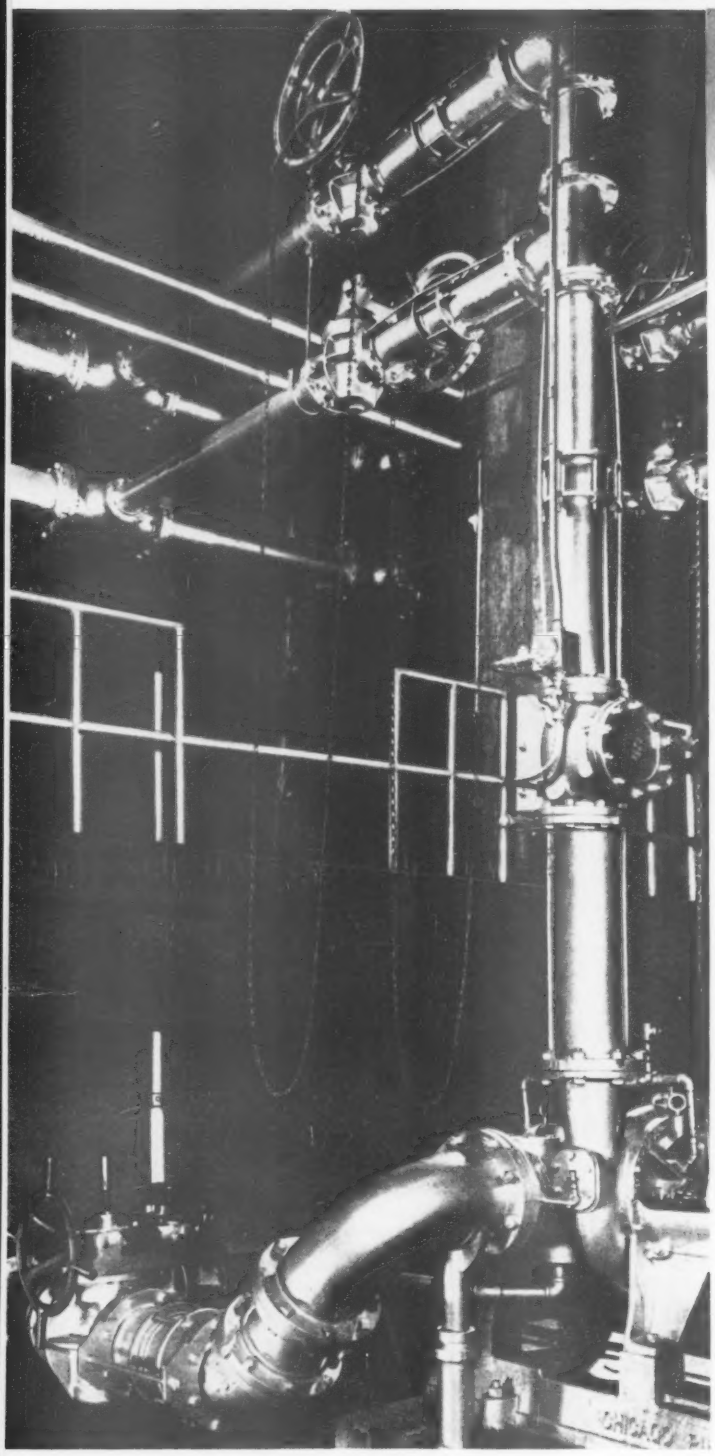
INFILCO INC.

Tucson, Arizona

Plants in Chicago and Joliet, Illinois

FIELD OFFICES IN 28 PRINCIPAL CITIES

INFILCO



FROM TOP TO BOTTOM

this sewage plant is Nordstrom equipped

In the sewage treatment plant shown in this picture, Nordstrom valves are installed on all types of lines from intake to discharge.

Why? Because Nordstroms are protected by a film of pressurized lubricant.

This lubricant surrounds seat ports preventing leakage . . . it protects the vital seating surfaces of a Nordstrom from wear, corrosion, erosion or abrasion . . . it keeps the valve ready to open or close with a quick quarter-turn at any time—reason enough to standardize on Nordstroms.

If you are building a new sewage treatment plant or replacing the valves in your present one, call your Nordstrom representative for an estimate. Rockwell Manufacturing Company, Pittsburgh 8, Pa.

ROCKWELL Built Nordstrom Valves

Lubricant-Sealed for Positive Shut-Off

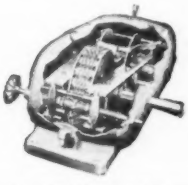
Another ROCKWELL Product

LINK-BELT sanitary engineering equipment is built to last with LINK-BELT components

IN municipalities and industrial plants all over the country, Link-Belt water, sewage and waste treatment equipment provides reliable, efficient service. There are two important reasons for this outstanding record—

First, Link-Belt designs are based on broad experience and sound engineering . . . assure the finest in modern treatment techniques. Second, and equally important—Link-Belt equipment is built to the highest standards with Link-Belt power transmission and conveying components. This is your guarantee of long-life, high-efficiency operation.

The Link-Belt line includes coarse and fine screens, grit and sludge collectors for grit chambers and settling tanks, scum breakers for digestion tanks and sludge handling equipment. Our sanitary engineers will be glad to work with your engineers, chemists and consultants—help you get the best in modern treatment equipment. Call the Link-Belt office near you for complete information.



P.I.V. VARIABLE SPEED DRIVE

For positive, infinitely variable speed selection. Choose from 16 types, ½ to 25 hp, reduction ratios 6:1.

GEARMOTORS

Safe, compact, efficient. Output speeds from 6 to 280 rpm in standard line of double and triple reduction units.

ELECTROFLUID DRIVES

Hydraulic coupling combined with induction motor for smooth starting and shock load protection. Avoids "over-motoring."

WORM GEAR DRIVES

Suited to high-ratio reductions, with vertical or horizontal output shafts. Quiet, smooth, compact. Output rpm: 0.22 to 564.

ROLLER CHAIN

For positive power transmission at high or low speeds, coordinating rotation of numerous shafts. Long or short centers.

PROMAL CHAIN

This stronger, longer-wearing malleable alloy has toughness, strength, high yield point, high resistance to abrasion.

BELT CONVEYOR IDLERS

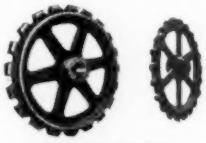
Husky, self-aligning roller bearings maintain alignment. Grease in-dirt out seals preserve lubricant longer.

SCREW CONVEYORS

Sectional flight and helicoid types. One moving part. Compact. No return run. Horizontal, vertical or inclined operation.

BALL & ROLLER BEARINGS

Full line of precision pillow blocks, flanged; flanged cartridge, cartridge, hanger, and take-up blocks for every need.



SPROCKET WHEELS

Teeth are accurately cast and hand ground to fit chain correctly. A type for every chain, a size for every requirement.

PEAK CAP BEARINGS

Water lubricated, Self-Aligning; prevent accumulation of sludge on all submerged bearings of Collectors.

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Plants: Chicago, Indianapolis, Philadelphia, Colmar, Pa., Atlanta, Houston, Minneapolis, San Francisco, Los Angeles, Seattle, Toronto, Springs (South Africa), Sydney (Australia). Sales Offices, Factory Branch Stores and Distributors in Principal Cities. 13,144-A

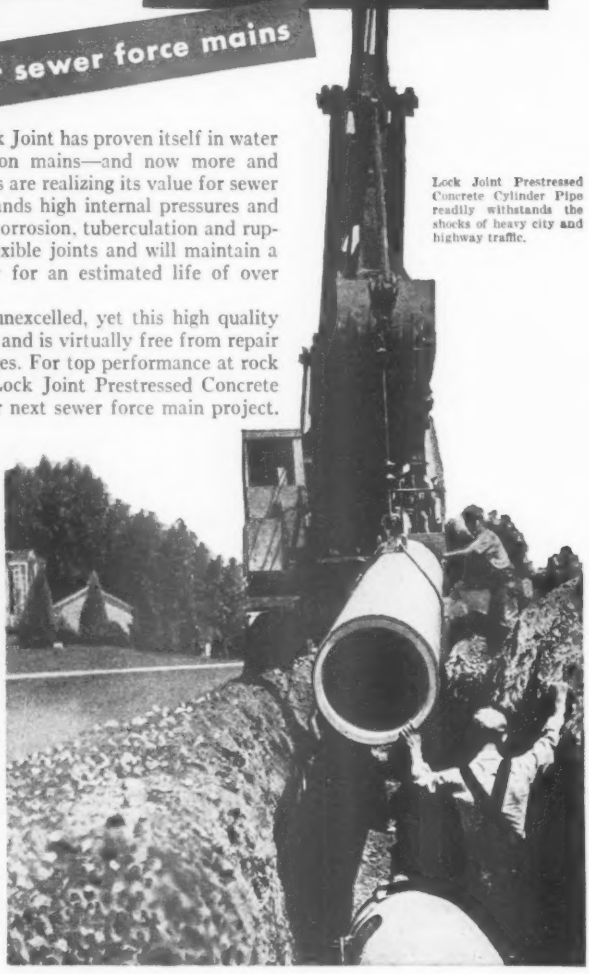
LOCK JOINT

the ideal pressure pipe

for sewer force mains

Through the years Lock Joint has proven itself in water supply and transmission mains—and now more and more sanitary engineers are realizing its value for sewer force mains. It withstands high internal pressures and external loads, resists corrosion, tuberculation and rupture, has watertight flexible joints and will maintain a high carrying capacity for an estimated life of over 100 years.

Its performance is unexcelled, yet this high quality pipe is low in first cost and is virtually free from repair and maintenance charges. For top performance at rock bottom cost, specify Lock Joint Prestressed Concrete Cylinder Pipe for your next sewer force main project.



Lock Joint Prestressed Concrete Cylinder Pipe readily withstands the shocks of heavy city and highway traffic.

Its ability to withstand heavy backloads frequently makes it possible to lay Lock Joint Prestressed Concrete Cylinder Pipe in deep cuts without special bedding. The speed with which it may be laid and the fact that it can be immediately backfilled usually makes it unnecessary to sheet the trench.

SCOPE OF SERVICES—*Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply Distribution Mains in a wide range of diameters as well as Concrete Pipes for Sanitary Sewers, Storm Drains, Culverts and Subaqueous Lines.*

LOCK JOINT PIPE COMPANY

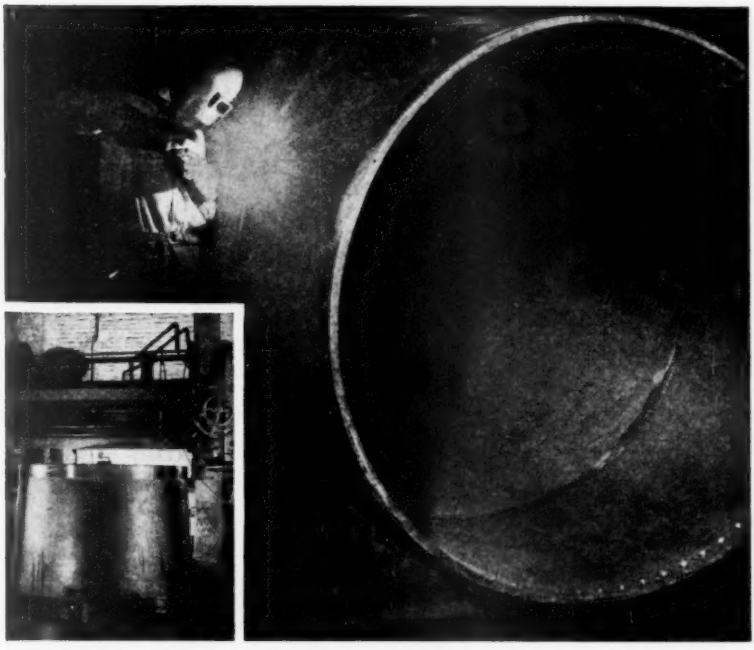
Est. 1905

P. O. Box 269, East Orange, N. J.

PRESSURE PIPE PLANTS:
Wharton, N. J., Turner, Kan., Detroit, Mich.

BRANCH OFFICES: Casper, Wyo. • Cheyenne, Wyo. • Denver, Col. Kansas City, Mo. • Valley Park, Mo. • Chicago, Ill. • Rock Island, Ill. Wichita, Kan. • Kenilworth, N. J. • Hartford, Conn. • Tucumcari, N. Mex. • Oklahoma City, Okla. • Tulsa, Okla. Beloit, Wis. • Hato Rey, P. R.

LOCK JOINT
Reinforced Concrete
PRESSURE PIPE



TAPERED small-end Everdur section, before being welded to large-end tapered section, is machined to fit throat at C. H. Wheeler Mfg. Co.

THROAT OR INTAKE END of the 2-section, 16-foot-long Venturi outlet cone. This throat is made by roll forming ⅝-inch Everdur-1010 plate at The Daniel Russell Boiler Works, Boston, Massachusetts. Here a seam is being welded by the Aircomatic® process using Everdur-1010 Welding Rod.

This Everdur Venturi Tube Meters 350,000 gpm Through New York's Neversink Tunnel

Metering that much water flowing through the new Neversink Tunnel of New York's Delaware Water Supply System at 235 psi static pressure at cone required an accurately fabricated, strong, corrosion-resistant Venturi outlet cone approximately 16-feet long with an 8-foot diameter tapering to 5 feet, 5 inches at the throat.

Such equipment, buried in the tunnel, must not fail—and Builders-Providence, Inc., the supplier, had to design to exacting specifications. Costs were also a factor. This huge cone was, therefore, designed for welded fabrication of ⅝-inch-thick Everdur*-1010 (ANACONDA Copper-Silicon Alloy) plate.

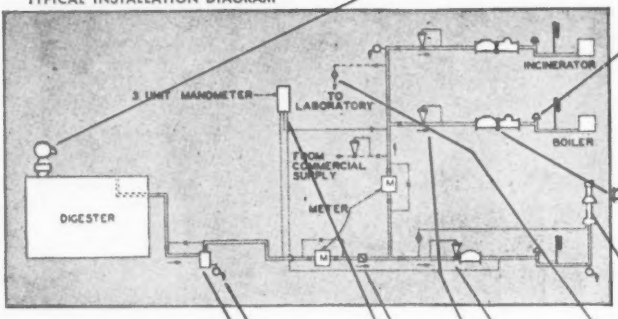
Depending on the alloy, you can work Everdur hot or cold, and easily form, forge, weld and machine it. Everdur is available in plates, sheets, rods, tubes, electrical conduit and casting ingots.

Our Technical Department's services are always yours for selecting the best and most practical material for your equipment. *The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.*

*Reg. U. S. Pat. Off. 52142A

EVERDUR
ANACONDA®
COPPER-SILICON ALLOYS
STRONG • WELDABLE • WORKABLE
CORROSION-RESISTANT

TYPICAL INSTALLATION DIAGRAM



"VAREC" Pressure Relief and Vacuum Breaker Valve with Flame Arrester — Fig. 5800C — Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.

"VAREC" Explosion Relief Valve—Fig. 70—Relieves sudden surges in pressure from explosion or momentary plant fluctuations.

"VAREC" Flame Trap Assembly—Fig. 450—Prevents flame propagation in piping.

"VAREC" Waste Gas Burner—Fig. 236, 237 or 238—Efficiently burns all excess gas.

"VAREC" Flame Check—Fig. 51A or 52A—Prevents flashback from burner pilot or laboratory burners.

"VAREC" Pressure Relief and Flame Trap Assembly—Fig. 440—Permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.

"VAREC" Pressure Reducing Regulator—Fig. 187 or 387—Controls pressure of gas going to utilization equipment.

"VAREC" Check Valve—Fig. 211 or 211A—Controls direction of gas flow.

"VAREC" Manometer—Fig. 215, 215A, 216 or 216A—Indicates system pressures.

"VAREC" Drip Trap—Fig. 245 or 248.

"VAREC" Sediment Trap — Fig. 230, 232 or 233 — Keeps lines drained and free from moisture.

Plan with "Varec" Symbols of Safety

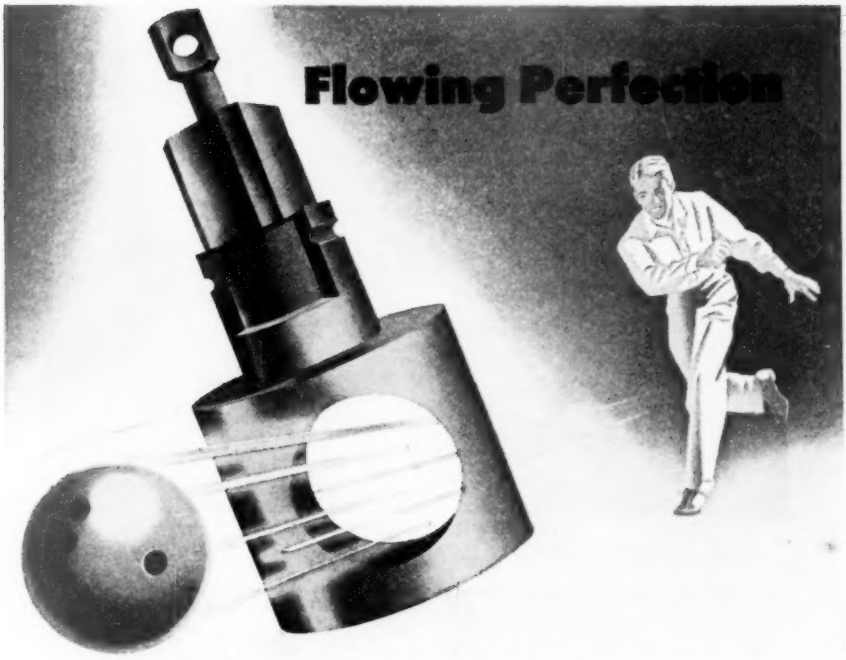
FOR GAS CONTROL THROUGHOUT YOUR SEWAGE TREATMENT PLANT

PROVED and APPROVED "Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

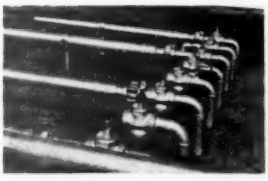
COMPTON, CALIFORNIA, U. S. A.

S-10 *Available from Authorized Sewage Equipment Agents throughout U. S. and Canada.*

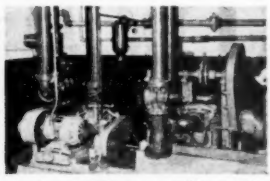


Straight through, clean as a whistle! That's the kind of *flow perfection* you get with an a.c.f. Round Port Valve. Because they're the exact same size and shape as the pipe itself, there are no obstructions. You *always* get full capacity flow of heavy viscous ladings . . . without loss in head pressure. There are no abrasive effects from solids in suspension.

The full pipe area and non-wedging effects of Round Port Valves are also found in a.c.f. Rectangular Port Valves. Both are designed to give you long, trouble-free service with minimum maintenance. Don't settle for less than the very best. It pays!



The Petroleum Industry finds full-pipe area of a.c.f. Valves of great advantage on both natural gas and crude oil.



In Sewage Treatment Plants the a.c.f. exclusive Cylindrical Plug shears obstructions, provides uninterrupted flow.

In Processing a.c.f. Round Port Valves are 100% obstruction free, ideal for handling materials in suspension.

a.c.f. CYLINDRICAL FULL PIPE AREA PLUG VALVES

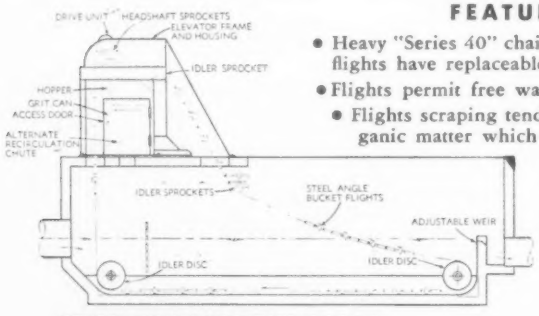
Write for Catalog 4-SI. American Car and Foundry Company, Valve Division, 1501 E. Ferry Ave., Detroit 11, Michigan.

Representatives in 50 Principal Cities

UNIONTOWN, PA. INSTALLATION
THE CHESTER ENGINEERS, PITTSBURG, PA. — CONSULTANTS

DETENTION TYPE BASINS WITH SELF-ELEVATING GRIT COLLECTOR

The grit collecting-elevating mechanism shown below is well adapted for situations where construction space is limited, fine grit is present and where the collected grit must be elevated to a considerable height. The V-buckets are specially designed for high capacity loads to reduce operating time and wear. Collected grit may be discharged to containers, or to cross conveyors for removal to trucks or receiving bins outside of grit chamber.



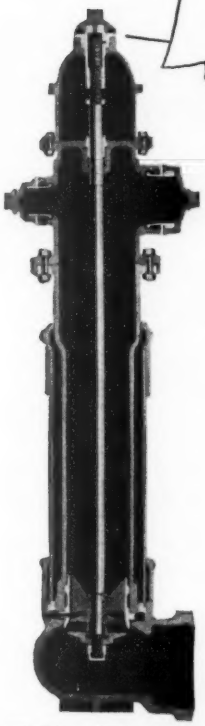
FEATURES

- Heavy "Series 40" chain with steel bucket flights have replaceable wearing shoes.
- Flights permit free water to drain.
- Flights scraping tend to free settled organic matter which is in turn washed out of tank.
- Grit recirculation (adjustable) gives absolute control over putrescible content.

WRITE FOR BULLETIN 21563

WALKER PROCESS

WALKER PROCESS EQUIPMENT INC.
FACTORY • ENGINEERING OFFICES • LABORATORIES
AURORA, ILLINOIS



No other hydrant is so inexpensive to maintain— so quick and easy to repair

- **The Mathews Hydrant is so simply and soundly constructed that there's virtually nothing to go wrong.**
- **Only one point needs lubrication—the operating thread—and that only during routine inspections.**
- **A Mathews Hydrant broken in a traffic accident can be quickly repaired *without excavating* and nozzle levels can be adjusted with the same ease.**
- **For community fire protection, rely on Mathews Hydrants, the standard of the industry.**

MATHEWS HYDRANTS

Made by R. D. Wood Company

Public Ledger Building, Independence Square, Philadelphia 5, Pa.

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

150th anniversary

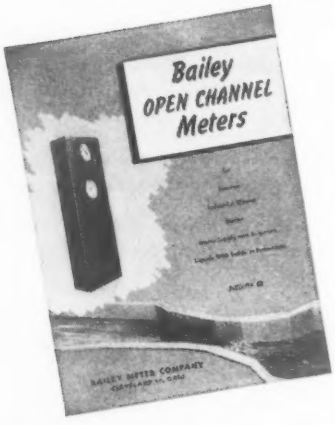
NO OTHER HYDRANT OFFERS SO MANY ESSENTIAL FEATURES

Compression type valve prevents flooding • Head turns 360° • Replaceable head • Nozzle sections easily changed • Protection case of "Sand-Spun" cast iron for strength, toughness, elasticity • All operating parts contained in removable barrel • A modern barrel makes an old Mathews good as new • Available with mechanical-joint pipe connections

For trouble-free, low cost measurement of —

SEWAGE
INDUSTRIAL WASTES
SLUDGE
IRRIGATION WATER

BAILEY
OPEN CHANNEL METERS
Offer These Advantages:



1. Easy to Install
2. Retain Accuracy
3. Self-Cleaning
4. Adjustable Capacities
5. Totalize Multiple Flows
6. Chemical Feed Control
7. Flow and Ratio Controls

Ask for Bulletin 62

MU22

BAILEY METER COMPANY

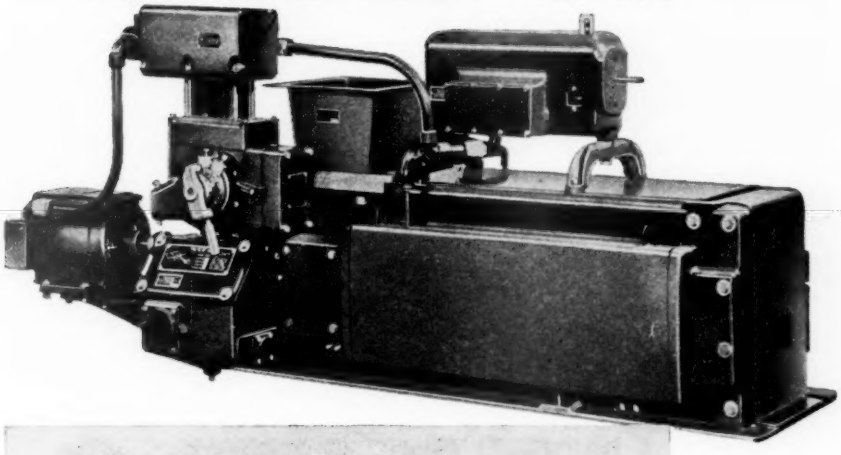
1066 IVANHOE ROAD • CLEVELAND 10, OHIO

METERS and CONTROLS for SEWAGE and WATER

VENTURI TUBES, FLUMES, WEIRS, NOZZLES, ORIFICES • DIRECT MECHANICAL AND REMOTELY LOCATED REGISTERS • AIR-OPERATED, ELECTRONIC AND ELECTRIC CONTROLS.

The best "WEIGH" . . . is the MERCHEN way!

W&T Merchen Feeders give precision feeding of any waterworks chemical . . . *by weight.*



FEATURES:

—Continuous, minute-to-minute accuracy.

—Durable construction, sealed bearings and dust shields.

—Automatic built-in alarm switch.

—Knife edges and pivots tipped with special alloy for long life.

—Remote feed rate adjustment if desired.

—Adaptable to fully automatic proportional control.

Hundreds of installations feeding waterworks chemicals, industrial chemicals and feed and flour ingredients have proved the accuracy and dependability of these belt-type gravimetric feeders.

M-24

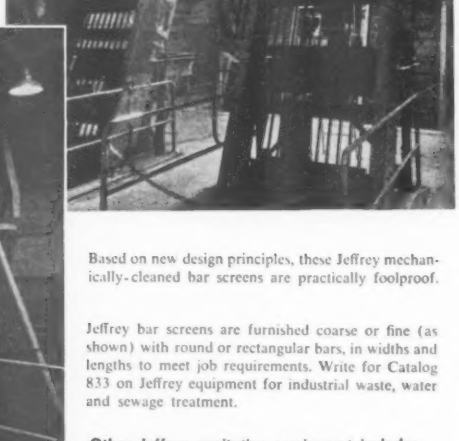
USE W&T FEEDERS FOR
Dependable Chemical Control

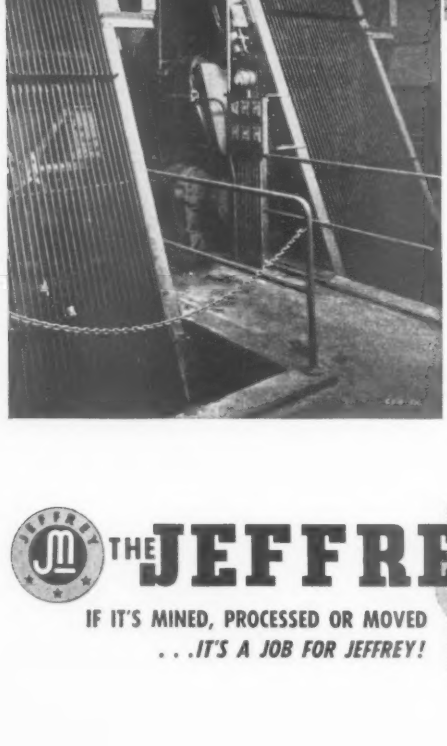
WALLACE & TIERNAN
COMPANY, INC.
CHLORINE AND CHEMICAL CONTROL EQUIPMENT
NEWARK 1, NEW JERSEY — REPRESENTED IN PRINCIPAL CITIES

for dependable performance...
low maintenance...

Jeffrey BACK-CLEANED Screens

The treatment of water, sewage and industrial waste by mechanical means has definitely proved to be most effective and economical. It is now the accepted standard for new plants, including those for small villages.





Based on new design principles, these Jeffrey mechanically-cleaned bar screens are practically foolproof.

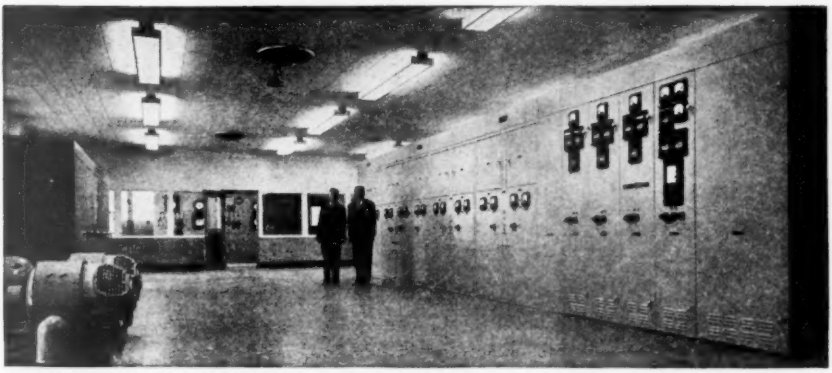
Jeffrey bar screens are furnished coarse or fine (as shown) with round or rectangular bars, in widths and lengths to meet job requirements. Write for Catalog 833 on Jeffrey equipment for industrial waste, water and sewage treatment.

Other Jeffrey sanitation equipment includes:

Screening Grinders
Grit Collectors and Washers
Sludge Collectors for Primary and Final Settling Tanks
FLOCTROLS (Controlled Flocculation)
Belt and Spiral Conveyors
Chains and Sprockets
Scum Removers
Dry Feed Chemical Machines
Biofiltration Plant Equipment
Garbage Grinders
Bucket Elevators
Power Transmission Machinery
Hydrolese Hubs
Constant Weight Feeders

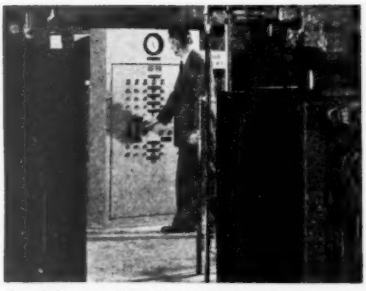
THE JEFFREY MANUFACTURING CO.
ESTABLISHED 1877
Columbus 16, Ohio
sales offices and distributors in principal cities
PLANTS IN CANADA, ENGLAND, SOUTH AFRICA

IF IT'S MINED, PROCESSED OR MOVED
. . .IT'S A JOB FOR JEFFREY!



Typical of modern G-E equipment is this switchgear and Limitamp control lineup at a new west coast plant.

3-way aid for your Clean Waters plan



Special control like this chlorinator panel is part of complete G-E equipment for sewage plants.

Available now to all communities faced with the need for new or expanded sewage-treatment facilities is this three-way help from General Electric:

1. **Community-action program,** including the film *Clean Waters* to aid you in increasing public support for necessary new projects.
2. **Engineering assistance** to your consultants or engineers in electrical-system planning.
3. **Co-ordinated electrical equipment** supplied from the complete G-E line of motors, control and power distribution equipment.

To take advantage of this complete service, contact your nearest G-E Apparatus Sales Office early in the planning of your project. General Electric Co., Schenectady 5, N. Y. 666-75

Clean Waters program consists of film, manual *Modern Sewage Treatment*, handout leaflets.

G-E motors for sewage-plant use range from these large lift-pump motors to small motors for process drives.

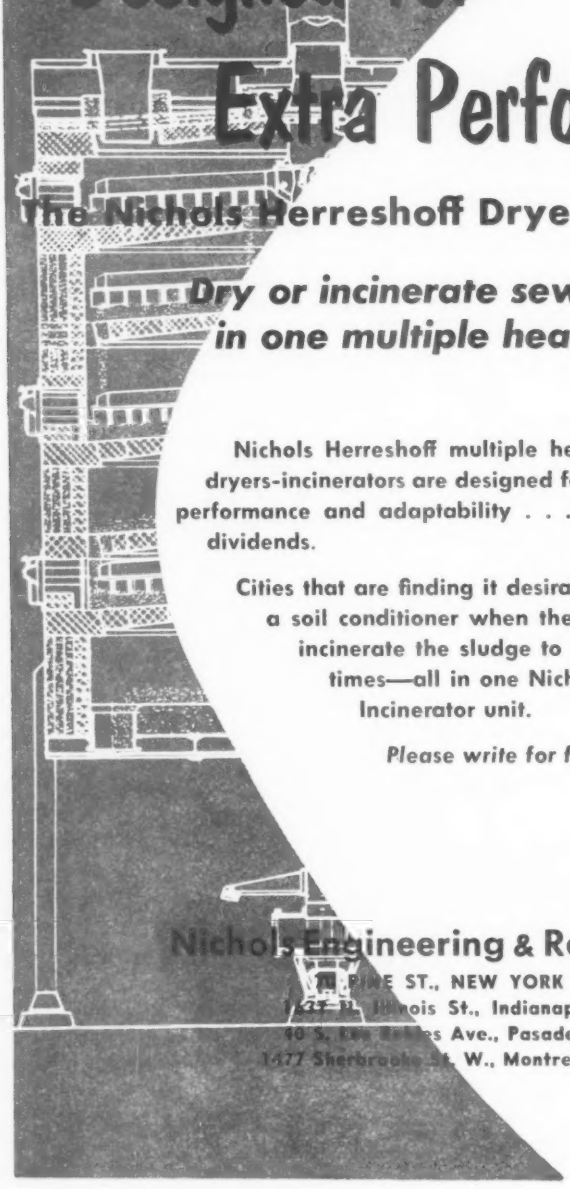
Engineered Electrical Systems for Sewage Plants

GENERAL ELECTRIC

Designed for Extra Performance

The Nichols Herreshoff Dryer-Incinerator

Dry or incinerate sewage sludge in one multiple hearth unit



Nichols Herreshoff multiple hearth sewage sludge dryers-incinerators are designed for something extra in performance and adaptability . . . an extra that pays dividends.

Cities that are finding it desirable to dry sludge for a soil conditioner when there is a demand, can incinerate the sludge to a sterile ash at other times—all in one Nichols Herreshoff Dryer-Incinerator unit.

Please write for further information.

Nichols Engineering & Research Corp.

11 PINE ST., NEW YORK 5, N. Y.
1477 N. Illinois St., Indianapolis 2, Ind.
40 S. Los Robles Ave., Pasadena 1, Calif.
1477 Sherbrooke St. W., Montreal 25, Canada

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 25 **November, 1953** **Number 11**

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Mrs. A. H. Skates, *Editorial Assistant*

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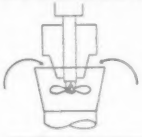
In Sludge Digestion... you need all 4!

Effective, two-stage, sewage sludge digestion involves far more than just a heated tank! There are four major — and interrelated — requirements.

Here they are . . . and here's what you need to meet them . . .

1. Homogeneous mixing and elimination of scum

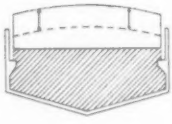


Calls for intensive mixing in the Primary by means of high-capacity propeller and draft tube.

2. Simplified Sludge Heating

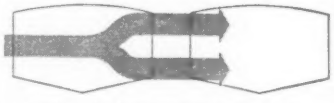
Requires an efficient heat exchanger of *simplified* design . . . without excessive and complex instrumentation.

3. Adequate Gas Storage



Demands a Secondary equipped with a movable, steel dome gas holder to even out fluctuations and insure a constant supply to gas utilization equipment.

4. Simplified Control



Requires a simple and automatic means of transferring sludge and liquor from the Primary to the Secondary at rate of feed.

Most important of all . . . you need a balanced and integrated System to meet these needs economically. Not an expensive conglomeration of unrelated units.

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Sewage Works

RESEARCH ON ACTIVATED SLUDGE

I. A Study of the Aeration of Water

By A. Pasveer

Research Institute for Public Health Engineering, National Health Research Council, The Hague, Netherlands

Despite the voluminous literature on activated sludge, comparatively little has been reported in the way of fundamental research on brush aeration or on the minimum requirements of aeration tank capacity. This series of papers, therefore, reports research on activated sludge as carried out at the Research Institute for Public Health Engineering, a facility of the Netherlands National Health Research Council.

The first paper, dealing with a study of the aeration of water, shows that the rate of solution of oxygen in water in motion cannot be calculated without recourse to experiment; and that the rate of diffusion is inversely proportional to $\sqrt{t}$, an important concept in any investigating of the nature of the diffusion process. The second paper reports experiments in brush aeration heretofore given only very limited distribution. The third paper deals with the distribution of oxygen in activated sludge floc, and the fourth with experiments in the purification capacity of activated sludge under very intense aeration.

Notation

The following letter symbols, used in this series, conform essentially to the standard letter symbols as given in the various publications of American Standards Association:

A = area of the interfacial surface;
A' = hypothetical area of the interfacial surface;
c = concentration of gas:
c_G = concentration of gas in the gas mass;
c_L = concentration of gas in the liquid;
c_p = concentration of gas in the monomolecular gas layer;
c_q = concentration of gas in the monomolecular liquid layer;
c_{L_s} = concentration of gas in the liquid at saturation;
H = Henry's constant (c_G/c_{L_s});
h = height of the column of liquid into which the gas diffuses;
k = diffusion constant:
k_L = diffusion constant of gas in the liquid;
k_G = diffusion constant of gas in the gas mass;
Q_d = quantity of diffused gas;
S = rate of diffusion $\left(\frac{dQ_d}{dt}\right)$;
t = time;
t' = time of subsistence of the hypothetical surface of a liquid at rest;
V_L = volume of liquid; and
$\rho = H\sqrt{k_G/k_L}$.

Solution of Gases in Liquids at Rest

When studying the theoretical aspect of the solution of gases in liquids it is expedient to take as a basis a simple theoretical case; specifically the diffusion of a pure gas, G, in a state of perfect rest in a column of infinite length, which gas at time $t = 0$ is brought into contact with a column of liquid, L, likewise in a state of perfect rest and of infinite

length. At the moment contact is established between the gas and the liquid, a state of equilibrium is at once produced in the monomolecular interfacial layers. It can, for instance, be shown by calculation that when non-oxygenized water is brought into contact with atmospheric air the monomolecular water layer becomes saturated with oxygen molecules within a time of the order of 10^{-7} sec.

Immediately after the establishment of contact between the gas and the liquid the monomolecular liquid layer becomes saturated with the gas, which marks the commencement of the process of diffusion of the gas from the monomolecular layer to the deeper layers. The rate at which the diffusion process takes place is governed by Fick's law.

Fick's law, however, is difficult to apply just as it stands. As far back as 1878 Stefan (1) worked out more simple relationships deduced from Fick's law for a number of possibilities propounded in theory. One of these simple cases is the problem previously formulated (Figure 1).

For this purpose the gaseous atmosphere is considered to consist of a pure gas. This means that, even if there are no currents in the gas mass, the number of gas molecules supplied to the liquid as a result of the high velocity of the gas molecules is so great that the composition of the monomolecular gas layer at the interfacial surface is identical with that of the rest of the gas mass ($c_p = c_G$, hence $c_q = c_{Ls}$).

Stefan gives the following relationship for the rate of progress of the

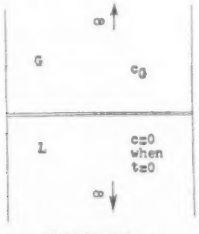

FIGURE 1.

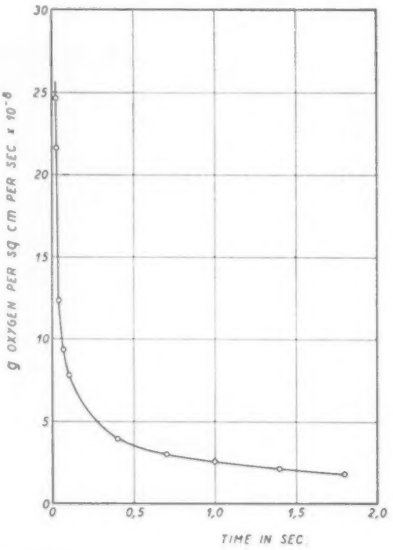

FIGURE 2.—Rate of solution of oxygen in quiescent water at 10° C.

diffusion of the gas, G, into the liquid:

$$Q_d \text{ per sq. cm.} = 2\, c_q \sqrt{\frac{k_L t}{\pi}} \quad \ldots (1)$$

if, when $t = 0$, $c = 0$; and also, in general:

$$Q_d = 2\, A\, (c_q - c_L) \sqrt{\frac{k_L t}{\pi}} \quad \ldots (2)$$

Eq. 2 shows that the amount of diffused gas is proportional to the square root of the time. The rate of the diffusion process is greatest immediately after the formation of the gas-liquid interfacial surface and afterwards decreases rapidly with the time (Figure 2).

The next case to be examined is one in which the pure gas, G, in the previous example is replaced by a gas mixture, $G + F$, in which F does not dissolve in the liquid or in which the liquid is saturated with F (Figure 3).

At the moment of formation of the interfacial surface a state of equilibrium will again be produced at the interfacial surface, this time between the molecules of the gas G in the mono-

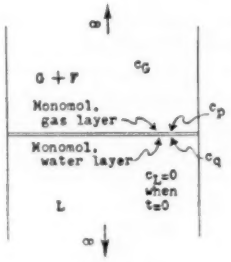

FIGURE 3.

molecular gas layer and those in the monomolecular liquid layer. Also, as before, gas is removed by diffusion into the deeper layers of the liquid. In this case it must not be taken for granted that the degree of concentration in the monomolecular gas layer remains equal to that obtaining in the gas mass, as the molecules of gas that have passed from the interfacial surface into the liquid must be replenished by diffusion from the gas mixture.

It can be calculated that, in the theoretical case in which diffusion takes place in columns of infinite length, the concentration of the diffusing gas in the monomolecular layers of gas and liquid is constant and can be equated as a known value in the expressions:

$$c_p = \frac{\rho}{\rho + 1} c_G \ldots\ldots\ldots (3a)$$

and

$$c_q = \frac{\rho}{\rho + 1} c_{Ls} \ldots\ldots\ldots (3b)$$

If, for the moment, any differences in k_G and k_L of the different gases are ignored, the value of ρ will be governed by Henry's constant. In the case of gases of poor solubility, H will have a high value and the value of $\frac{\rho}{\rho + 1}$ will approximate 1, because for one thing $\sqrt{\frac{k_G}{k_L}}$ invariably has a high value. In this case c_p will differ only slightly from c_G. On the other hand, in the case of gases of good solubility the value of H is small and $\frac{\rho}{\rho + 1}$ differs considerably from 1. In the latter case there is a considerable difference between c_p and c_G, and hence between c_q and c_{Ls}.

The foregoing presents the theoretical aspect of the diffusion of a gas into a liquid at rest, taking as its basis Eq. 1, deduced by Stefan, as applicable respectively to the diffusion of a gas from a gas mixture and to the diffusion of a gas into a liquid. The formulas used apply to the theoretical case in which diffusion is considered for gas in columns of infinite length. It is now of particular importance to examine how far the diffusion formulas adopted and the reasoning based thereon will hold good in circumstances where the stated requirement as to the gas columns is not fulfilled.

Stefan made a detailed investigation of the conditions under which the formulas evolved by him are applicable. His conclusion was to the effect that Eq. 1 shows no greater divergence than

TABLE I.—Column Length and Maximum Diffusion Time at which Stefan's Formula is Applicable

Column Length (cm.)	Max. Diffusion Time at Which Divergence < 2%
0.01	2.7 sec.
0.05	68 sec.
0.1	4.5 min.
0.5	110 min.
1.	7.5 hr.
5.	8 days
10.	30 days

TABLE II.—Diffusion Time and Minimum Column Length at which Stefan's Formula is Applicable

Diffusion Time (sec.)	Min. Column Length at Which Divergence < 2% (cm.)
0.01	0.0006
0.1	0.002
0.5	0.004
1.	0.006
10.	0.02
100.	0.06
300.	0.1
600.	0.15

1 per cent as long as the condition is fulfilled that

$$\frac{\pi^2 k\, t}{h^2} < 3,$$

and no greater divergence than 2 per cent as long as the value of this expression < 4. Therefore, if k is known, the range of conditions over which Eq. 1 applies can be calculated for each individual case. Tables I and II give some data for the case of the diffusion of oxygen in water.

Solution of Gases in Liquids in Motion

The course of events during solution in liquids in motion is in theory exactly the same as in the case of liquids at rest. The difference in practice is that, to an extent dependent upon the degree of mixing (turbulence), the surface layer becomes mixed after a longer or shorter time with the rest of the liquid, in which the gas may undergo further dispersion (also as a result of diffusion and mixing). New layers are added to the surface continuously. Another possible course of events is that although the surface layer remains the same for a longer or shorter time, the layers situated more or less closely below the surface will be replaced continuously by other layers. The decline in concentration in the case of water at rest, as determined by time and the diffusion constant, will undergo interference as a result of mixing. The chances are that this interference will not occur in the same way at every point on the interfacial surface. The course of events cannot be approximated mathematically.

One may imagine as substitute for this interference by turbulence with the decline in concentration a state of affairs in which the surface is replaced at certain time intervals by a new surface of the same area which remains during its subsistence in a state of perfect rest. It must also be assumed that the interfacial layers below the disrupted surface are instantaneously mixed with the rest of the liquid.

If the time of subsistence of this hypothetical surface be designated as t', this means that the surface is renewed $\frac{1}{t'} = n$ times during unit time. In the case of a gas of poor solubility, in which $c_0 = c_{L_s}$, for the time of subsistence t',

$$Q_d = 2\,A\,(c_{L_s} - c_L)\sqrt{\frac{kt'}{\pi}} \quad \ldots (4)$$

from which

$$\frac{dc}{dt} = 2\,n\,\frac{A}{V_L}\sqrt{t'}(c_{L_s} - c_L)\sqrt{\frac{k}{\pi}} \quad \ldots (5)$$

By integration over the time elapsing from t_0 to t_1, where c_L varies from c_0 to c_1,

$$2n\,\frac{A}{V_L}\sqrt{\frac{kt'}{\pi}} = \frac{1}{t_1 - t_0}\,ln\,\frac{c_{L_s} - c_0}{c_{L_s} - c_1} \quad (6)$$

It is thus possible, in the case of a gas of poor solubility, to ascertain experimentally the value of

$$n\,\frac{A}{V_L}\sqrt{t'} = \frac{A}{V_L}\,\frac{1}{\sqrt{t'}}$$

The right side of this expression is a measure of the rate at which gas is supplied to the liquid. If the conditions of the experiment are such that a certain value of the hypothetical surface area may be considered more or less acceptable, the time of subsistence of the hypothetical surface area can be found by calculation. The more powerful the turbulence, the more the value of $\frac{A}{V_L}\,\frac{1}{\sqrt{t'}}$ will increase.

Discussion

It was found in the foregoing that the amount of oxygen absorbed by the water is proportional to the square root of the time. This datum, which although known is usually not accorded the prominence it deserves, is a valuable help in forming a clear idea of the diffusion process. It shows that the diffusion process is a slow one if time

is reckoned in hours and days, but that it is a very rapid process when dealing with aeration times amounting to fractions of seconds.

During the aeration of water the rate of diffusion of oxygen from the interfacial surface into the water is a maximum at the moment of formation of the interfacial surface. This rate decreases very rapidly with the time. Hence it follows that the energy employed for aeration as far as possible should be directed towards the creation of a new interfacial surface and not towards the maintenance of the interfacial surface already formed.

In the study of the solution of oxygen in water in motion, use is made of two formulas, *viz.:*

1. That of Adeney and Becker.
2. That of Black and Phelps.

Adeney and Becker (2) studied the rate of solution of oxygen in water in motion with the aid of the "rising bubble" method evolved by them, regarding which they state the following:

". . . and it was found that the conditions prevailing when a large bubble is allowed to ascend a narrow tube filled with water, were almost exactly those sought. In this case the surface tension keeps the water-air surface unbroken during its passage up the tube, and since the bubble occupies nearly the whole cross-section of the tube, the water is exposed to the air in an extremely thin layer, while the upward movement of the bubble produces a very perfect local mixing of the water."

By this method it is possible to calculate the water-air surface, which varies but little in the course of the experiment. The thickness of the aerated layer of water and the period of aeration can likewise be ascertained. The amount of air (oxygen) which dissolves in the water (the experiment being started with non-aerated, that is, non-oxygenated water) is calculated from the diminution in volume of the air bubble. The data required for drawing up a calculation are then known.

Adeney and Becker base their mathematical deductions on the principle that the rate of solution of a gas (oxygen) in water is determined by the ratio between the oxygen molecules entering the interfacial surface and those escaping from it, provided the water is well-mixed (that is, that the concentration at the surface is equal to that obtaining in the mass of the liquid).

It has been shown in the foregoing that, at a water-gas interfacial surface, the relationship $c_g = \frac{\rho}{\rho + 1} c_{Ls}$ is applicable, which in the case of oxygen (that is, a gas of very poor solubility), at the very high values for ρ, means $c_g = 99.9\%\ c_{Ls}$.

It follows, therefore, that in the case of water not saturated with oxygen the concentration at the interfacial surface is never equal to that of the entire mass of liquid. The "well-mixed" condition can never be fulfilled. The mathematical deduction of Adeney and Becker is thus shown to be incorrect, with the result that their formula is of no value for calculating the rate of solution of oxygen in water in motion.

This is confirmed by Adeney and Becker's own observations. They found an increasing value for their "coefficient of escape" (which must be a constant) according as the volume of the air bubble becomes greater.

They explained this by stating that the conditions at the top of the air bubble are different from those ruling in the cylindrical part and that this is more strongly evidenced in the case of a small air bubble. This explanation is incorrect. The effect of the lower speed at the top of the air bubble is offset by the thicker layer of liquid over which the absorbed oxygen has to be distributed. The true explanation is to be found in the longer aeration times in the case of the larger air bubble, resulting in a lower average rate of diffusion.

It is of particular interest to note that, on checking the experiments of

Adeney and Becker, good agreement is found to exist between the values established experimentally by Adeney and Becker and the values calculated by means of the formula for diffusion in water at rest. In a specific case, values of 10.51 and 9.82 per cent, respectively, were found for a double passage of the air bubble. It thus follows that the flow of water past the air bubble will for the most part be in the form of a laminar film. If this were not the case, much higher values would have been found in the experiment. The rising bubble method evolved by Adeney and Becker for water in motion thus proves to be more suitable for determining the rate of solution in water at rest.

Black and Phelps (3) also use a formula derived from Fick's law for calculating the rate of solution of oxygen in water at rest. Working partly by mathematical deduction and partly with the aid of graphs, they arrive at the relationship:

$$\log R_0 = 1.85 + 0.5 \log K \ldots (7)$$

in which R_0 represents re-aeration at 100 per cent deficit, and

$$K = \frac{\pi^2 at}{4L^2} \ldots\ldots\ldots (8)$$

in which L is depth and a is the diffusion coefficient.

From Stefan's formula Eq. 7 can be shown to be in the exact form

$$\log R_0 = 1.85633 + 0.5 \log K \ldots (9)$$

It should be mentioned that in Eq. 8, the diffusion coefficient, a, has the value of $\pm$ 0.07 sq. cm. per hr. and not 1.42 sq. cm. per hr. as given by Phelps. The "International Critical Tables" (Vol. 5, p. 63) give $K_{18^\circ} = 1.98 \times 10^{-5}$ sq. cm. per sec. (that is, 0.0713 sq. cm. per hr.)

In order to use Eq. 7 for the rate of solution in water in motion it is necessary to introduce an empirical factor. It is then better to use the formula given by Phelps (5)—

$$D_t = D_a\, 10^{-k_2 t} \ldots\ldots (10)$$

—which expresses the relation between the deficit D after any time t, the initial deficit D_a, and the coefficient of re-aeration, k_2.

As Phelps states, the selection of k_2 requires experimental judgment and, generally, is checked against stream survey data of the specific watercourse involved.

Theory and practice thus teach that in the case of water in motion, even so-called well-mixed water, the rate of aeration cannot be calculated theoretically. For each special case an experimental determination is necessary.

Conclusions

1. Since the rate of diffusion is proportional to $\frac{1}{\sqrt{t}}$ (t = aeration time), diffusion during very brief aeration times is an extremely rapid process.

2. It follows from conclusion 1 that the rate of diffusion is a maximum at the moment of formation of the oxygen-water interfacial surface and afterwards decreases rapidly as a function of the time (Figure 2).

3. It follows from conclusion 2 that the energy employed for aeration should be directed towards the creation of a new water-air interfacial surface.

4. Theoretical considerations show that the basis of the formula of Adeney and Becker for calculation of the rate of solution of oxygen in water is incorrect.

5. In the case of water in motion, the rate at which oxygen is absorbed can never be calculated without recourse to experiment.

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VALUE OF CULTURE AND ENZYME ADDITIONS IN PROMOTING DIGESTION *

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Digestion of sewage solids is the result of biochemical activities of bacteria. These activities comprise the hydrolysis and liquefaction of complex organic materials by enzymes secreted by bacteria, the enzymes converting these materials into simpler, intermediate, soluble, or more readily available forms. The intermediate soluble products diffuse through the cell membrane and are ultimately assimilated and converted into final end products such as methane, carbon dioxide, and possibly hydrogen, leaving an undigestible humus-like residue. Development of the bacteria necessary to bring about these various complex biochemical changes takes place naturally in fresh solids kept under proper environmental conditions for a time. The digested sludge, which harbors a great number of the organisms necessary for the various phases of digestion, serves as seed for the digestion of additional raw sludge. Thus the process is perpetuated by the retention of a sufficient quantity of digested sludge as long as the proper environmental conditions are maintained.

From time to time, especially recently, claims have been made that addition of cultures of bacteria, or of certain enzyme preparations produced by them, promotes digestion. Recent claims of this nature have been made for a preparation called Enzymatic (1), which is said to promote the reduction of solids and B.O.D. of sewage and bring about other beneficial effects, such as reducing scum in septic tanks. A report by Bryan (3) indicates that another biological preparation called Bionetic, which is said to consist of a group of preserved living microorganisms, enzymes, and some trace minerals, when added to overloaded digestion tanks, improved the quality of supernatant liquor in respect to suspended solids in B.O.D.

If bacterial cultures or their enzymes are to prove of any value they might be used in two different ways. First, they might be used as initial cultures to shorten the "working-in" period required to establish digestion. Second, they might be added to a tank in which digestion has been established, in order to accelerate the digestion. Of the two methods, the first would seem to be of greater promise on the basis of the considerations previously advanced.

If such preparations accelerate the digestion they should prove equally effective whether the digestion is carried on in septic tanks, Imhoff tanks, or separate sludge digestion tanks.

The purpose of this paper is to produce experimental evidence to determine the value of some of the biological preparations consisting of enzymes and/or bacterial cultures on the digestion of sewage solids. In addition, an experiment was also conducted to determine the effect of yeast addition on the digestion despite the fact that in an earlier paper (2) the senior author was unable to find any evidence that yeast accelerated anaerobic digestion. Experiments were conducted by adding these preparations to otherwise sterilized or unsterilized unseeded raw sludge, as well as by adding them to properly seeded raw sludge and ripe sludge mixtures.

In addition, one of the preparations

* Paper of the Journal Series, New Jersey Agricultural Experiment Station.

was added to sewage to determine whether an effluent with a lower B.O.D. could be obtained after sedimentation in settling or septic tanks.

Procedures and Methods

In the experiments dealing with the effect of addition of biological preparations to raw sludge, the yardstick used for measuring the effect was the B.O.D. of the supernatant. The basic concept in the use of this yardstick was that in the absence of gasification the addition of the biological preparations would result in accelerated liquefaction-conversion of complex sludge solids to soluble and colloidal forms, which would register a higher B.O.D. in the supernatant liquor. During the comparatively short periods used in these experiments (1 to 2 weeks) there was little, if any, gasification in the absence of ripe sludge. The products of hydrolysis and liquefaction should, therefore, accumulate in the liquor and register a higher B.O.D. than the liquor obtained from the control without the addition of the preparation. It was necessary to separate the sludge particles from the supernatant. This was accomplished by centrifuging and filtering the sludge mixture. The experiments were conducted with both heat sterilized (autoclaved) and unsterilized fresh solids.

In the experiments dealing with the effect of the addition of the preparations to ripe and raw sludge mixtures, the important yardsticks used were gas production and solids reduction. The basic concept here was that whether the preparation consisted of enzymes or enzymes and bacterial cultures, the net effect on a possible acceleration should be a higher rate of gas production and solids reduction over a similarly prepared seeded mixture without the addition of biological preparation.

Various concentrations of the preparation were used according to the manufacturers' instructions and in many instances in concentrations several times higher.

The following preparations were employed:

1. Pure preparations as follows:

(a) Special Diastase HT Concentrate. It is obtained from a special strain of *Bacillus subtilis* with considerable proteolytic activity in addition to diastatic activity converting starches and glycogen to maltose.

(b) Clarase 900. A very concentrated diastatic enzyme obtained from *Aspergillus oryzae* and similar in its action to the Special Diastase.

(c) Cellulolytic enzyme obtained from *Rhyzopus*, capable of hydrolyzing cellulose and pectin.

(d) Pectinase. Stronger in its action on pectin than the cellulolytic enzyme, but free from cellulolytic activity.

(e) Pancreatin, with a hydrolyzing action on fats, proteins, and starches.

2. Preparation A. A special enzyme preparation, claimed to consist of more than 70 enzymes belonging to the groups of esterases, sulfatases, carbohydrases, amylases, amidases, and proteolytic enzymes, for use in home septic tanks.

3. Preparation B. It consists of living bacteria and enzymes.

4. Baker's yeast.

Results

The results obtained by the addition of pure enzymes to sterilized fresh solids are given in Table I. Two separate runs were made. In the first run, samples were taken after 12 hr. and after 5 days. In the second run, samples were taken only after 18 hr. The results show definite increases in the B.O.D. of the supernatant liquor after 12-hr. incubation with each of the enzymes used separately and with the combination of the five enzymes. The minimum increase was obtained with pancreatin and the maximum with the combination of all five enzymes. Greater increases in B.O.D.

TABLE I.—B.O.D. of Supernatant in Sterile Fresh Solids

Additive	Run 1				Run 2	
	12 Hours		5 Days		18 Hours	
	(p.p.m.)	Increase (%)	(p.p.m.)	Increase (%)	(p.p.m.)	Increase (%)
1. Control	1,680	—	765	—	4,200	—
2. Special diastase[1]	2,400	43	1,370	80	5,160	23
3. Clarase[1]	2,430	45	1,200	57	5,190	24
4. *Rhyzopus* enzyme[1]	2,220	32	1,760	130	5,200	24
5. Pectinase[1]	2,400	43	1,370	79	5,070	21
6. Pancreatin[1]	1,890	12	1,200	57	5,190	24
7. Combination of 5 enzymes[2]	2,580	54	1,590	110	5,380	28

[1] 0.1 g. of enzyme added per liter of fresh solids.
[2] 0.02 g. of each enzyme added per liter of fresh solids.

were obtained after 5 days of contact than after 12 hr. with each of the enzymes, although in this case there is a question about the validity of the B.O.D. value of the control. It is difficult to account for the decrease in the B.O.D. value of sterile fresh solids upon incubation for 5 days. It is reasonable that the B.O.D. remained unchanged, and on this basis there should be little difference between the control and the enzymes after 5 days. In the second run, significant but not quite as high increases were obtained after 18-hr. contact as in the first run after 12-hr. contact.

The results of the addition of enzymes to the unsterilized fresh solids are given in Table II. There was no significant increase in the B.O.D. of the supernatant after 18-hr. contact in the first run with any of the enzymes or the combination of all five enzyme additions. In the second run, only diastase and clarase gave appreciable increases in the B.O.D. after 18 hr., but none of the other enzymes or the combination of enzymes gave an increase.

Another method of approach was used to determine the effect of these pure enzymes on the digestion of sewage sludge. In this case the enzymes were added to a properly seeded fresh solids ripe sludge mixture and the gas production and volatile matter reduction yardsticks were used to compare the effect of enzymes with a similar mixture without the addition of enzymes. A concentration of 100 p.p.m. of the Special Diastase and a total concentration of 100 p.p.m. of the mixture of all five enzymes, as reported in Table I, was used. Gas production was measured daily for a period of 39 days and initial and final solids and volatile matter contents were determined, from which the reduction of volatile matter during the period of digestion was calculated. The results

TABLE II.—B.O.D. of Supernatant Liquor from Fresh Solids[1]

	Run 1		Run 2	
	(p.p.m.)	Diff. (%)	(p.p.m.)	Diff. (%)
1. Control	5,220	—	1,440	—
2. Special diastase[2]	5,460	+5	1,875	+30
3. Clarase[2]	4,500	−13	1,640	+14
4. *Rhyzopus* enzyme[2]	5,220	0	1,440	0
5. Pectinase[2]	5,460	+5	1,560	+8
6. Pancreatin[2]	5,340	+2	1,500	+4
7. Combination of 5 enzymes[3]	4,980	−5	1,530	+6

[1] After 18-hr. contact.
[2] 0.1 g. of enzyme added per liter of fresh solids.
[3] 0.02 g. of each enzyme added per liter of fresh solids.

TABLE III.—Effect of Addition of Pure Enzymes on the Gas Production and Volatile Solids Reduction of Seeded Sewage Sludge Mixtures

Additive		Gas[1] (ml./g. vol.)	Final pH[2]	Volatile Reduction (%)
Type	Conc. (p.p.m.)			
Control		635	7.0	37.0
Special diastase enzyme	100	650	7.1	35.0
Mixture, 5 different enzymes	100	626	7.0	37.0

[1] Digestion period, 39 days.
[2] Initial pH 6.2.

(Table III) show that the additions of enzymes did not increase the gas yield or affect the volatile matter reductions and pH values.

The results obtained with the addition of proprietary preparation A are given in Table IV. The 50 mg. of the preparation added to 1 l. of sterilized or non-sterilized fresh solids represent a greater concentration than recommended by the manufacturer. The B.O.D. obtained in the supernatant after 1, 2, 4, and 7 days contact was compared with the corresponding controls similarly treated except for the addition of enzyme. The results show that the B.O.D. of the liquor obtained from sterile fresh solids fluctuated during 7-day incubation slightly within the experimental error. The corresponding values obtained from the sterilized fresh solids to which the enzyme preparation was added were not materially different from the corresponding controls. Similarly, in the unsterilized series the addition of enzyme preparation did not give a significant change in the B.O.D. of the supernatant over the control.

The results from a similar study with the addition of a preparation B (Table V) show no significant difference in

TABLE IV.—Effect of Addition of Enzyme Preparation A on the B.O.D. (in P.P.M.) of Supernatant Liquor from Fresh Solids

Substrate	Digestion Period			
	1 Day	2 Days	4 Days	7 Days
1. Fresh sterile solids	5,235	5,130	5,100	5,370
2. Fresh sterile solids + 50 p.p.m. Preparation A	5,235	4,890	5,070	5,370
3. Fresh solids	5,070	6,270	5,580	5,940
4. Fresh solids + 50 p.p.m. Preparation A	5,190	5,535	5,760	5,970

TABLE V.—Effect of Addition of Culture Preparation B on the B.O.D. (in P.P.M.) of Supernatant Liquid from Fresh Solids

Substrate	Digestion Period		
	2 Days	5 Days	8 Days
1. Fresh solids	6,840	6,480	6,240
2. Fresh solids + 2,700 p.p.m. Preparation B	6,090	5,400	6,420
3. Fresh sterile solids	5,460	5,880	5,880
4. Fresh sterile solids + 2,700 p.p.m. Preparation B	5,850	6,000	5,400

TABLE VI.—Rate of Oxidation of Supernatant Liquor from Fresh Solids (in P.P.M.); 8-Day Contact

Substrate	Days				
	0.5	1	1.5	3.0	5.0
Fresh solids	470	2,880	3,210	3,930	4,800
Fresh solids + Preparation A	615	2,940	3,120	3,960	4,950
Sterile solids	610	2,800	—	4,170	4,650
Sterile solids + Preparation A	900	2,750	2,820	3,870	4,880

the B.O.D. of the supernatant due to the addition of the preparation with the sterilized and unsterilized fresh solids during the course of 8-day incubation.

It was thought possible that the addition of the preparations might increase the rate of oxygen consumption in the B.O.D. bottles during the initial periods of incubation without necessarily increasing the 5-day B.O.D.'s. Accordingly, B.O.D. determinations were made after 0.5, 1, 3, and 5 days of incubation on the supernatant liquors obtained in sterile and unsterile fresh solids after 8 days of contact with the enzyme. The results (Table VI) indicate that the B.O.D. exerted with 0.5-day incubation was somewhat higher in the supernatant liquor obtained after addition of preparation A to sterile and non-sterile fresh solids than the corresponding supernatants to which no such additions were made. But the B.O.D. values obtained with 1-, 1.5-, 3-, and 5-day incubation periods were the same in the controls as with the additions. It does not appear, therefore, that the rate of oxygen utilization is increased materially as a result of treating the sludge with this preparation.

To 600 ml. of fresh solids containing 20 g. of volatile matter, 20 g. of yeast were added. The control consisted of a similar volume of fresh solids without yeast. In addition, 20 g. of yeast suspended in water were also used. These three preparations were incubated at 20° C. for 56 days with daily gas measurements. The results are summarized in Table VII. The gas yield is expressed on the basis of volatile matter of fresh solids. A somewhat greater volume of gas is obtained from the fresh solids to which yeast was added than from the fresh solids alone. The yeast alone produced a considerable volume of gas. When the volume of gas produced from the yeast itself is subtracted from the fresh solids yeast mixture, the gas yield from the fresh solids portion of this mixture is not appreciably higher than the fresh

TABLE VII.—Effect of Yeast on the Digestion of Fresh Solids

	Fresh Solids	Fresh Solids Plus Yeast	Yeast Alone
Digestion time (days)	56	56	56
Gas (ml./g. vol. in fresh sol.)	27.5	68	36
pH, initial	5.3	5.3	—
pH, final	4.6	5.0	5.7
Dry solids, initial (%)	4.40	7.73	3.33
Dry solids, final (%)	2.86	3.34	1.09
Vol. sol. dry basis, initial (%)	75.5	86.4	88.0
Vol. sol., dry basis, final (%)	70.3	74.6	86.7
Vol. sol. wet basis, initial (%)	3.32	6.65	2.96
Vol. sol. wet basis, final (%)	2.01	2.49	0.95
Vol. matter reduction (%)	39.5	62.5	67.5

TABLE VIII.—Effect of the Addition of Enzyme Preparation A on the B.O.D. of Sewage (in P.P.M.)

Additive	Digestion Period				
	0 Day	1 Day	2 Days	4 Days	6 Days
Control	155	160	157	105	74
50 p.p.m.	160	144	156	109	82
100 p.p.m.	168	153	165	117	80

solids digesting without yeast addition. The pH value of the fresh solids-yeast mixture was somewhat higher after 53 days than in the fresh solids alone. The changes in the solids and volatile matter contents of the fresh solids with and without yeast additions and of the yeast alone are also given in Table VII. The solids content of the yeast alone decreased greatly, resulting in a 67.5 per cent reduction in volatile solids, which probably accounts for the higher volatile solids reduction of the fresh solids-yeast mixture than the control. In other words, it does seem likely that the addition of yeast resulted in a greater reduction of volatile matter in fresh solids.

In order to determine the effect of enzyme preparation A on the claimed reduction in the B.O.D. of sewage upon passage through septic tanks, an experiment was conducted by adding 50 and 100 p.p.m. of this preparation to settled sewage and storing it under quiescent conditions for 6 days at 20° C. At intervals, samples of supernatant were withdrawn without mixing the contents of the vessel, and 5-day B.O.D. determinations were made. The control consisted of a sample of the same sewage handled in a similar way except for the addition of enzyme preparation. The results (Table VIII) give no indication that the addition of enzyme preparation resulted in any improvement in the B.O.D. of the sewage up to 6 days of storage.

Discussion

The addition of biological preparations, such as enzymes or bacterial and yeast cultures, to promote the digestion of sludge in septic tanks or sludge digestion tanks, would be of value in starting new tanks or in accelerating digestion of overloaded tanks if there was proof of their beneficial effect. There are, however, three lines of evidence against such a possibility. They are based on theoretical, practical, and experimental considerations.

On an *a priori* theoretical basis, the use of enzymes does not offer a promising outlook. There is no doubt that hydrolysis of disaccharide, such as sucrose, to glucose can be brought about by bacteria-free enzyme invertase; of starch into glucose by diastase; of proteins by a number of proteolytic enzymes; and of fats by lipolytic enzymes. In fact, in certain cases, such as when recovery of the products of hydrolysis is the objective, there is a distinct advantage in bringing about the transformation by enzyme preparations rather than bacterial cultures, because the latter would carry the transformation to completion to the final end products. It is generally true that of the two types of reactions—bacterial and enzymatic—the latter is less efficient than the former. The question arises as to why these hydrolytic exo enzymes, when secreted into the medium by the living bacteria in culture, should be more efficient than the same enzymes in bacteria-free substrate.

The reasons for this phenomenon are complex and technical. Enzymes as true catalysts should theoretically not be consumed by the processes they bring about and should be regenerated so that starting with a given quantity of an enzyme the process should go to completion without their utilization or destruction. In bacteria-free preparations this may be true to a certain extent, although even under this condition the rate of reaction is not as high as with bacterial cultures because (a) certain enzymes, such as trypsin, inactivate themselves; (b) enzyme reactions are reversible and the products

formed, which in bacteria-free enzyme reactions would naturally accumulate, bring the reaction to a stop by virtue of the equilibrium concentration established; and (c) each enzyme has its own optimum pH value. In the presence of mixed bacterial cultures the inactivation, utilization, and destruction of the added enzymes would be greater than in pure enzyme reactions.

The foregoing discussion has been from the standpoint of pure enzyme reactions in substrates containing relatively simple soluble organic compounds. In sewage sludge such compounds do not exist in a similar state of subdivision. There are no soluble sugars, starches, and proteins, but rather complex polysaccharides, cellulose, proteins, and fats associated with suspended large particles. Since hydrolytic enzyme reactions are surface contact phenomena, it can readily be seen why an enzyme preparation cannot bring about as efficient a reaction when added to the substrate containing coarse solids. In the case of hydrolysis brought about by bacterial cultures with coarse suspended particles, bacteria can and often do attach themselves to these particles and secrete the enzymes *in situ* to hydrolyze and solubilize these particles in preparation for diffusion into and assimilation by the cells. An illustration of this is the attachment of bacteria to cellulose fibers. Under such a condition the hydrolysis can be brought about more efficiently by bacteria-secreted enzymes than if the enzyme preparations were added to the suspension of fiber. In this way not only a greater concentration of enzyme is obtained at the site, but also a continuous production of enzyme from the potential reservoir of bacterial cell. The products formed from bacteria and the enzyme system could diffuse readily into the cell without accumulating in the substrate and thereby slowing up the reaction. Furthermore, the inactivation of the enzyme would not play a role, as there will be a continuous production of the enzyme. There is also the fact that in many of these hydrolysis reactions with complex organic materials there is involved more than one enzyme, which the bacteria produce readily in proper sequence for the specific reactions, whereas in the arbitrarily selected enzyme preparations some of the important enzymes required may be overlooked.

Normally the hydrolysis phase of the complex organic materials in the presence of bacteria proceeds rapidly and does not constitute the rate controlling factor. It is, rather, the diffusion into and the breakdown and assimulation of the products of hydrolysis within the cell that is the slower and rate controlling reaction, and the addition of extra-cellular enzymes into a substrate by no means can accelerate this phase nor can this phase be brought about by extra-cellular enzymes in the absence of living cells.

The addition of bacterial culture preparations could not result in material improvement in digestion for the following *a priori* reasons:

1. All the bacteria necessary for the digestion are present in the raw solids.
2. These bacteria are normally few in number in the raw solids, but they multiply and establish themselves under favorable environmental conditions.
3. Even during the initial period prior to the establishment of flora responsible for digestion, the addition of cultures of bacteria normally does not result in shortening the period of maturation and adjustment unless proper environmental conditions are established, and if these conditions are at an optimum the rapid rate of multiplication of the bacteria normally present in the raw sludge could establish the necessary flora without the aid of artificial additions of cultures. In other words, one can add a great number of bacteria artificially, but unless the conditions are conducive for their

multiplication, the benefit derived will be negligible and if the environmental conditions are at an optimum the organisms present in the raw sludge multiply and establish the necessary flora. The important consideration is the multiplication of the bacteria, with the resultant biochemical activity, rather than the existence of a large number of bacteria. Furthermore, it is unlikely that the diverse bacteria necessary for the digestion are included in the artificial culture, because so far the exact types of organisms involved in the digestion have not been isolated or studied.

Practical considerations also work against the use of enzyme and bacterial preparations. In a septic tank the additions of enzymes or bacteria are generally made to the sewage before entering the tank. Since these preparations are in a highly dispersed state, it is very probable that the major portion will pass out of the tank and will not settle to the sludge zone where the digestion takes place. In order to bring these preparations in contact with the sludge, either the entire tank contents have to be disturbed by mixing, which is contradicted from the standpoint of septic tank operation, or some means have to be found to introduce and distribute these preparations in the sludge zone. At the time when the tank is cleaned, these preparations might be placed in the bottom of the tank in solid form with the expectation that they might take effect as the new sludge is deposited. But even under these conditions the sewage flow would cause dispersion and solution, with the resultant loss into the effluent. It would seem more practical to leave some of the old sludge in the tank instead of completely removing it, and to rely on the seeding value of this sludge. With newly installed tanks, unless some sludge can be obtained from another tank in which digestion has been established, reliance should be placed on the natural seeding and establishment of the flora. These practical difficulties do not apply to the addition of enzyme and bacterial preparation to separate sludge digestion tanks. Here, the preparations can presumably be added with the raw sludge fed, with the expectation that they will be distributed within the tank, if they can be proved beneficial in the digestion of overloaded tanks or in shortening the period for the establishment of digestion in a new tank. The loss of the added preparations with the supernatant liquor withdrawn would be of minor importance.

What then is nature of the experimental evidence demonstrating the value of the various preparations for which certain claims have been made? The evidence available in the published literature seems rather inconclusive and is not based on rigidly controlled experimental work. The results presented in this paper on the basis of controlled comparisons does not show any evidence of improvement due to the addition of any enzymes, preparations of enzymes, bacterial cultures, and yeast to sterile and nonsterile fresh solids and to sewage, with a single exception. The exception is the indicated higher B.O.D. values of supernatant liquor when pure and strong enzyme preparations were added to sterile fresh solids. On the other hand, when these same enzymes were added to the unsterilized fresh solids, there was no increase in the B.O.D. of the supernatant. It shows that when bacteria and their enzymes are destroyed it is possible to get liquefaction of the complex organic materials by the use of artificially added strong enzymes; but in the presence of bacteria and their enzymes, as found in fresh solids, artificial addition of enzymes does not increase liquefaction.

Summary and Conclusions

A series of experiments was run by the addition of pure enzymes, enzyme and bacterial culture preparations, and

yeast, to determine their effect on the liquefaction of sterile and non-sterile fresh solids by using the increase of B.O.D. in the supernatant liquor as a yardstick. An additional experiment was run to check the claim that the addition of enzymes improves the quality of the effluent from septic tanks. The results obtained lead to the following conclusions:

1. The addition of pure enzymes, enzyme and bacterial preparations, and yeast, does not increase the liquefaction of non-sterile fresh solids as measured by the B.O.D. of the supernatant liquor.

2. The addition of pure enzymes to sterile fresh solids increases the B.O.D. of the supernatant liquid.

3. The addition of enzyme and bacterial preparations to non-sterile fresh solids does not result in an increased liquefaction as measured by the B.O.D. of the supernatant liquid.

4. The addition of an enzyme prepation to settled sewage did not result in increased stabilization and did not indicate an increase or decrease of B.O.D. after storage up to 6 days.

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BIOCATALYSTS AND WASTE DISPOSAL

II. Effect on Activated Sludge *

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In an effort to improve the operation of organic waste disposal systems, several biocatalysts have been introduced on the market. The biocatalysts are designed to increase the efficiency of existing plants and to solve various operational problems. Aside from technical bulletins issued by the manufacturers, very little information has appeared as to the merit of these biocatalysts. It is the purpose of this paper to present laboratory data as to the effect of two types of biocatalysts on activated sludge systems.

Previous Work

The use of the two types of biocatalysts examined in this study is not new. Ever since it was shown that biochemical reactions were catalysed by enzymes, investigators have speculated over pure enzymic treatment of sewage. One of the first efforts towards adding pure enzymes to an activated sludge system was tried by Rudolfs (1). His experiments were all negative and had a considerable effect on future studies involving enzymic treatment. The majority of investigations, as pointed out in the previous paper (2), dealt with a study of the various enzyme systems already present in activated sludge and other waste disposal processes.

Similar studies have been made concerning the use of pure culture bacteria by such investigators as Butterfield (3)(4), Ruchhoft *et al.*, (5)(6)(7) and McKinney and Horwood (8). Their investigations have all shown that pure cultures of bacteria are not as efficient as mixed cultures of bacteria, such as are found in sewage or in soil suspensions. But there is still speculation, as voiced by Fischer (9), that some day it might be possible to find combinations of certain strains of organisms that will operate more efficiently alone than in the combinations which predominate in present systems.

Materials and Methods

The two types of biocatalysts used in these experiments were concentrated bacteria, marketed as Bionetic, and concentrated enzymes, marketed as Enzymatic. Evaluation of the biocatalysts was based on the following:

1. The rate at which biochemical equilibrium was established in a new system.
2. The rate at which the B.O.D. of the waste was removed at equilibrium.
3. The variations in the biological character of the floc in the different systems.
4. The economics of the use of the biocatalysts.

Three substrates were tested—namely, a synthetic sewage, a raw sewage, and a synthetic industrial waste. These substrates permitted study of a wide range of conditions and loadings. The additions of the biocatalysts to the activated sludge systems were made at each feeding. It was impossible to add the dosages of Enzymatic as recommended by the manufacturer, because

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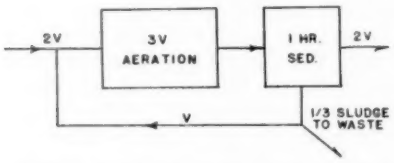

FIGURE 1.—Schematic diagram of activated sludge system simulated by laboratory units.

such small quantities could not be weighed accurately. As a result, the dosage of Enzymatic was approximately 100 times the recommended dosage. No information was available as to the dosage of Bionetics. To facilitate laboratory procedures, the dosages of both biocatalysts were made the same.

In order to simulate normal activated sludge in the laboratory, small aeration units were made from 1-gal. jugs. Each unit held 3 l. of mixed liquor and was operated in the following manner. At the end of each aeration period, 1 l. of mixed liquor was poured off and wasted. The remaining 2 l. were allowed to settle for 1 hr. before 1 l. of the supernatant was poured off. The desired amount of biocatalyst was then added in 2 l. of the fresh waste and aeration was started. At the end of the aeration period, this procedure was repeated. In this way it was possible to simulate an activated sludge system such as shown in Figure 1.

Synthetic Sewage

In the first series, three units were set up using a synthetic sewage as a substrate. Besides the two biocatalytic units there was a control unit, which served as the datum for comparing the efficiencies of the other two units. The synthetic sewage was a completely soluble organic substrate with the following formula:

200 mg. tryptone
200 mg. sucrose
50 mg. potassium phosphate, dibasic
100 mg. sodium bicarbonate
1,000 ml. tap water

Biologically speaking, this substrate

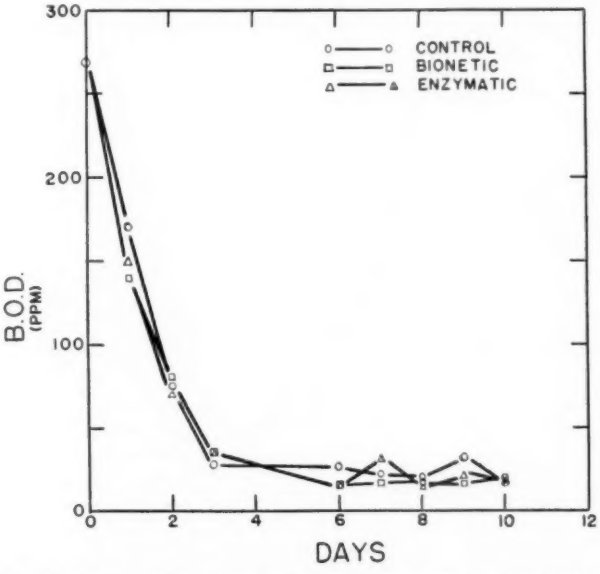

FIGURE 2.—B.O.D. of effluent from activated sludge units fed synthetic sewage and 100 mg. of catalysts twice daily after 24 hr. aeration.

was nutritionally stable and had a 5-day B.O.D. of 270 p.p.m.

All units were started by adding 1 l. of settled San Antonio sewage and 2 l. of synthetic sewage. To the two biocatalytic units 100 mg. of Enzymatic and Bionetic were also added. At the end of 24 hr. aeration, samples were taken for B.O.D. analyses as well as for microscopic analyses. The microscopic analyses indicated that considerable floc had formed. As a result, feedings were increased to twice a day. All analyses were made on the morning samples only. The data on the 5-day B.O.D. of the effluent (Figure 2) indicated that equilibrium was reached shortly after the third day. Average suspended solids concentrations ranged from 340 p.p.m. in the control to 370 p.p.m. in both the Enzymatic and Bionetic units once equilibrium was reached.

On the ninth day samples were taken hourly and filtered to remove the suspended solids. The 5-day B.O.D. of the supernatant was determined; equilibrium was reached around the sixth hour for all of the units (Figure 3).

Raw Sewage

Since the major portion of the food in the synthetic sewage was soluble organic matter, which was readily available to the bacteria, it was decided to test the biocatalysts on complex solids such as would be found in raw sewage. The raw sewage was obtained from the San Antonio sewage treatment plant at the time when the strongest sewage was entering the

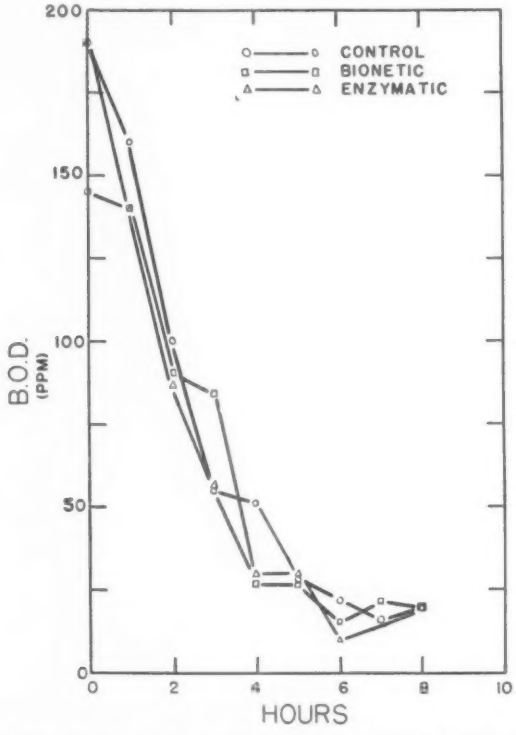

FIGURE 3.—B.O.D. of effluent from activated sludge units fed synthetic sewage and 100 mg. of catalysts; ninth day of operation.

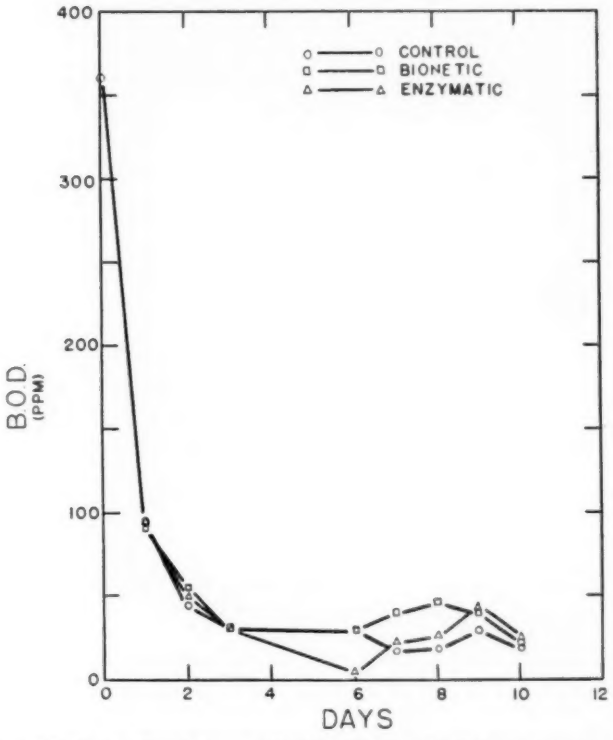

FIGURE 4.—B.O.D. of effluent from activated sludge units fed raw sewage and 100 mg. of catalysts twice daily after 24 hr. aeration.

plant. The 5-day B.O.D. of this raw sewage averaged 360 p.p.m.

The units in this series were operated in the same manner as in the previous series. The 5-day B.O.D. results (Figure 4) followed similar paths for all the units. Equilibrium was reached on the third day. The suspended solids in the mixed liquor were definitely higher in this series than in the previous series. For the most part this was due to the complex organic-inorganic colloids present in this substrate. The suspended solids in the mixed liquor ranged from an average of 750 p.p.m. in the control to 1,170 p.p.m. in the Enzymatic unit.

On the ninth day of aeration hourly samples of the mixed liquor were taken as in the previous series. The 5-day B.O.D. determinations on the filtrate (Figure 5) show the immediate removal of the B.O.D. of the complex solids quite clearly. Approximately two-thirds of the total B.O.D. was removed immediately. The soluble B.O.D. removal is reflected in the first part of the curves. Around the sixth hour, the rate of hydrolysis of the complex solids appears to begin to exceed the rate of utilization of the hydrolysed end products. This accounts for the rise in B.O.D. at the seventh hour. Once again there were no differences in the removal rates of any of the units.

Synthetic Industrial Waste

As a final test it was decided to increase the concentration of organic matter to determine if that was the limiting factor. A synthetic industrial

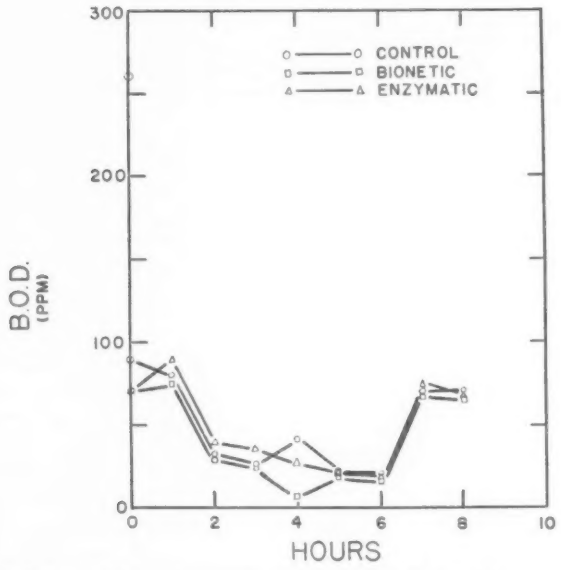

FIGURE 5.—B.O.D. of effluent from activated sludge units fed raw sewage and 100 mg. of catalysts; ninth day of operation.

waste was prepared from canned citrus juice. It was found that if canned citrus juice was diluted with 19 volumes of water, a 5-day B.O.D. of approximately 1,450 p.p.m. was obtained. The citrus juice was deficient in nitrogen, so ammonium chloride was added in sufficient quantity to give a B.O.D.-nitrogen ratio of 15:1. The waste was not deficient in phosphorus, but did require pH adjustment. A final pH of 6.9 was obtained in the feed by using phosphoric acid and sodium hydroxide. The pH rose on aeration to approximately 7.8.

Because of the increased organic content of the waste, the dosages of Bionetic and Enzymatic were increased to 500 p.p.m. The units were started in the same manner as in the two previous runs, using a sewage seed, and were operated in the same manner as the previous run with the exception that waste feedings were made once a day instead of twice. Figure 6 shows the 5-day B.O.D. of the effluents as they were obtained from the units at the end of each 24-hr. aeration period. Because of the complexity of the waste, equilibrium was not reached as rapidly in these units as in those of the previous two series.

As in the previous runs, hourly samples were taken and filtered. The 5-day B.O.D. was determined on the filtrate. Hourly runs were made on both the eighth and the sixteenth days. The results obtained on the eighth day are shown in Figure 7. Although there appears to be a slight difference in the paths taken during the stabilization of the waste, all units reached equilibrium at the same time, the sixth hour. The suspended solids in the mixed liquor in these units averaged approximately 1,300 p.p.m. The results obtained on the sixteenth day (Figure 8) show little improvement over the run on the eighth day. The suspended solids in the mixed liquor increased to 1,900 p.p.m.

Microscopic Examinations

One of the most important control tests in a biological waste disposal system such as activated sludge is rou-

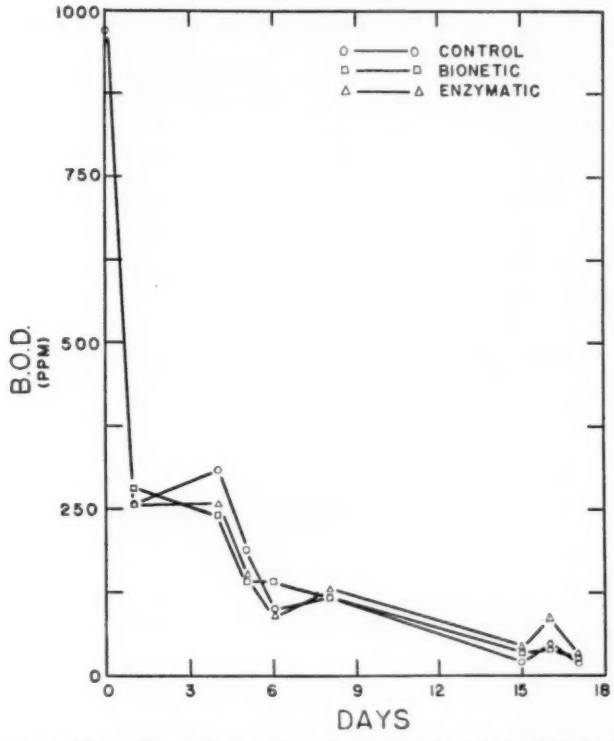

FIGURE 6.—B.O.D. of effluent from activated sludge units fed synthetic industrial waste and 500 mg. of catalysts daily after 24 hr. aeration.

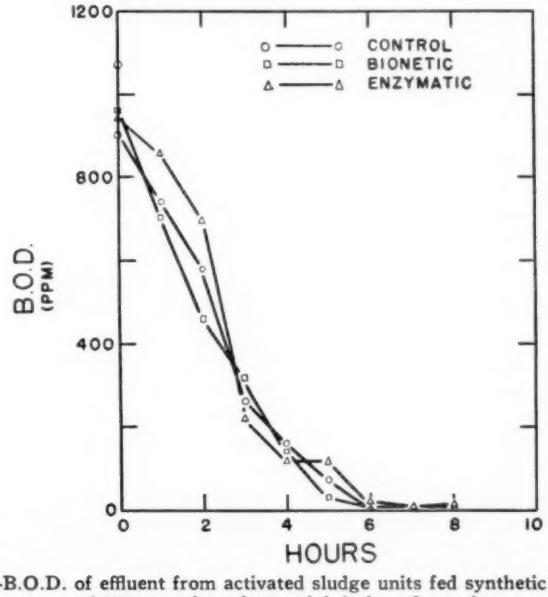

FIGURE 7.—B.O.D. of effluent from activated sludge units fed synthetic industrial waste and 500 mg. of catalysts; eighth day of aeration.

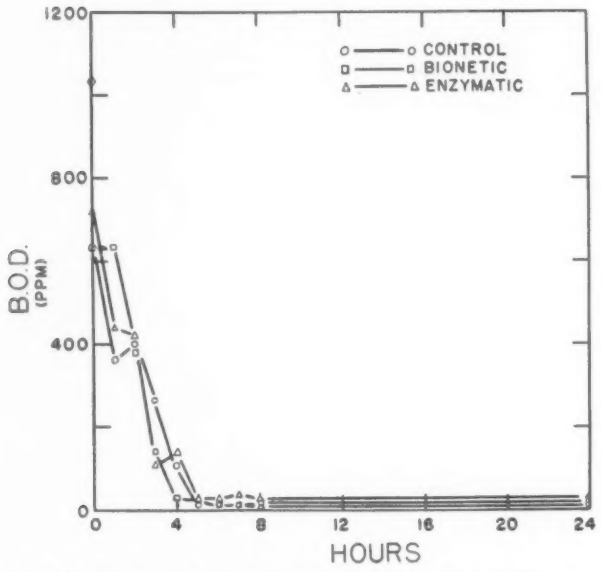

FIGURE 8.—B.O.D. of effluent from activated sludge units fed synthetic industrial waste and 500 mg. of catalysts; sixteenth day of aeration.

tine microscopic examinations. Repeated visual examination of the biological masses permits the observer to evaluate the conditions of a system in terms of the microorganisms. It is possible to foretell operational difficulties by observing changes in the microorganisms. Small changes in the biological floc are perceptible long before the changes are detectable by chemical analyses.

Microscopic examination of the activated sludges produced in the series of experiments revealed that the predominant organisms were different from series to series, but were similar within a given series. The microorganisms produced a light floc in the synthetic sewage run. It was predominantly composed of long-chained bacteria with small clumps of floc-forming bacteria. *Vorticella* were the predominate protozoa.

The floc formed from the raw sewage was typical bacterial floc built around organic-inorganic colloids, with *Vorticella* as the major protozoa. With the synthetic industrial waste, the sludge was light, due to filamentuous bacteria belonging to the genus *Sphaerotilus*. The floc was composed of small masses of bacteria, but lacked the mass normally furnished by inorganic colloids, which is necessary for rapid settling.

Discussion

The laboratory units were set up according to the accepted biological principles for activated sludge. From the data presented, the biocatalysts did not alter the normal biochemical pattern in any of the three series of experiments. The use of the biocatalysts did not increase the rate at which the biochemical equilibrium was reached in a new system. The rate of removal of B.O.D. was not increased and there was no visual difference in the nature of the biological floc. Since the biocatalysts failed to increase the efficiency of operation of the units over that of the control, there was no need

for consideration of the economics involved.

The normal growth of microorganisms was sufficient in the control unit to meet all needs as set forth by the three types of substrates. Bionetic, with its highly specialized microorganisms, did not add a sufficient number of new types of organisms to overbalance those found in the sewage used as seed. As to the relative number of organisms added by the Bionetic and those added by the sewage seed, there were approximately equal numbers. The hydrolytic enzymes of Enzymatic did not speed the metabolic reactions of the microorganisms in any way. In these systems the concentration of hydrolytic enzymes was not the critical factor in the biochemical equilibria.

Thus it can be seen that if an activated sludge system is designed and operated according to definite biochemical principles, there will not be any need for biocatalysts. Unfortunately, all of the biochemical principles concerning activated sludge are not known. There is a definite need for more research on the fundamental nature of activated sludge, as well as of all other forms of biological waste treatment systems. As new information is uncovered, it must be evaluated and made available to the engineer. All too often the engineer designing a biological waste treatment plant does not have a clear understanding of the biological phenomena taking place. And once the plant is constructed, operation often is intrusted to a technician who is completely unaware of the biological nature of the system he controls. Research must show the engineer that the biological waste treatment system must be designed from the biological aspect first and the structural and hydraulic aspect second, and both must show the municipalities and industries that the efficiency of operation can never exceed the knowledge and skill of the operator.

Summary

The results of the study reported here have shown the following:

1. The use of such biocatalysts as concentrated bacteria or concentrated enzymes did not increase the rate at which biochemical equilibrium was reached in a new activated sludge system over that of a sewage seeded control system.

2. The biocatalysts did not increase the rate of B.O.D. removal once equilibrium was reached.

3. There was no difference in the biological nature of the sludges produced by the biocatalysts and those produced by the sewage seeded control.

4. As long as an activated sludge system is designed and operated according to biological principles, the use of the biocatalysts studied will not increase the efficiency of plant operation.

Acknowledgment

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The Bionetic was furnished by Southwest Research Institute, which had obtained it from A. J. Krell of the Reliance Chemical Corp.; the Enzymatic was furnished through the courtesy of J. D. Cunningham of the N. O. Nelson Co.

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HANDBOOK OF BIOLOGICAL REFERENCES

An invaluable aid to those concerned with the biological phases of the field is the new "Handbook of Selected Biological References," recently published by the U. S. Public Health Service.

Designated as Public Health Service Publication No. 214, Public Health Bibliography Series No. 8, the 66-page handbook contains selected biological references on water pollution, sewage treatment, water treatment, and organism identification. The references have been selected largely on the basis of their availability and their potential usefulness to those not trained primarily in biology. Marine waters are not included.

Ease of use is a foremost quality of the handbook, as the references have been grouped under process headings in the cases of sewage and water treatment, and under suitable organism types in the case of water pollution control programs. References on organism identification are grouped under general headings and then under specific headings so as to expedite identification work. The entire compendium is not intended for use by the expert biologist, but by sanitary engineers, chemists, and bacteriologists dealing with the broad fields mentioned.

The handbook is available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at a price of 30 cents per copy.

TREATMENT OF WATER AND SEWAGE BY IONIZING RADIATIONS *

By Cecil G. Dunn

Department of Food Technology, Massachusetts Institute of Technology, Cambridge, Mass.

The purpose of the study reported here was to obtain data regarding the action of gamma rays from a kilocurie Co^{60} source on the bacteria found in water and sewage. Experiments were also conducted with the cathode radiation produced by a Van de Graaff type of generator at high voltages.

Co^{60} may be produced readily in kilocurie amounts in atomic piles. This radioactive material, a "mock" fission source, is convenient to study because of its known energy characteristics.

The germicidal action of high voltage X-rays and cathode rays, produced by a Van de Graaff generator, on a wide variety of microorganisms, including pathogens and non-pathogens, spore-formers and non-spore-formers, bacteria, yeasts, and molds has been studied by Dunn and associates (4)(9)(3) and others. Proctor *et al.* showed that spices (11), sheep casings, and other products (12)(13) may be sterilized by cathode rays produced at super voltages. As a matter of fact, it appears to be possible to sterilize almost any material with cathode irradiation. Huber (7) and Brasch and Huber (1) sterilized pharmaceutical and food products by cathode irradiation produced by a Capacitron. For further information along these lines, reference is made to the reviews by Proctor and Goldblith (12)(13).

Studies with Co^{60} on microbes and/or food products have been carried out by Proctor (10), Gaden (6), Lawrence (8), and Brownell (2).

Materials and Methods

A 1,000-curie Co^{60} source available in the Department of Food Technology at the Massachusetts Institute of Technology was used in this research. It was supplied to the Department through the Brookhaven National Laboratory. An approximate dose of 2,000 roentgens per minute was produced by the source during the period of this investigation. The energy of its gamma radiations amounts to 1.115 and 1.317 megaelectronvolts, respectively, and of its beta radiation to 0.308 megaelectronvolts. Its half life is 5.3 years (5).

The kilocurie Co^{60} source was calibrated by colorimetric and chemical means as described by Proctor and Goldblith (14). The Van de Graaff accelerator was calibrated by ionization techniques which have been discussed by Trump, Wright, and Clark (17). The doses given are averages of absorbed energy, wherein 1 r.e.p. equals 83 ergs absorbed per gram.

Views of the kilocurie Co^{60} source and the apparatus developed by Proctor and associates to handle samples are shown in Figures 1, 2, and 3.

Five-milliliter portions of the samples were placed aseptically in sterilized ampules and the latter were sealed before irradiation. Control samples in ampules were held at room temperature and iced in a refrigerator.

The cathode ray source was a Van

* Contribution No. 142 from the Department of Food Technology, Massachusetts Institute of Technology.

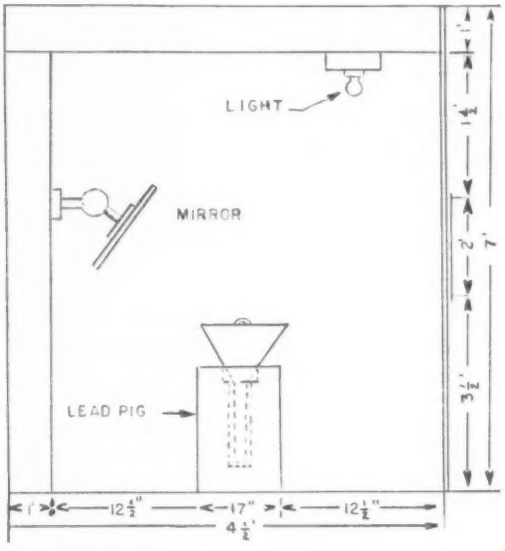

FIGURE 1.—Side elevation of vault for irradiation with Co^{60}.

de Graaff type of generator, which has been described by Trump and associates (15)(16). It was operated at 3 megavolts.

Five-milliliter portions of the samples were placed in sterilized glass dishes and covered with aluminum foil. Samples were irradiated on a moving belt. Doses of 250,000, or less, r.e.p. were usually applied in 1 sec., and doses of more than this amount and up to 2,000,000 r.e.p. were applied in 10 sec. or less.

All plating was done in duplicate to quadruplicate with Bacto nutrient agar. Incubation was at 37° C., usually for 24 hr.

Results

Data concerning the effect of ionizing radiations produced by the Co^{60} and cathode ray sources on the bacteria found in samples of water and sewage are given in Tables I and II.

Referring to Table I, it will be observed that from 88.3 to more than 99.9 per cent of the bacteria were destroyed within 25 min. by the kilocurie Co^{60} source, and that from 95.4 to more than 99.999 per cent were destroyed within 125 min. During the 25-, 50-, and 125-min. periods of irradiation, doses of approximately 50,000, 100,000, and 250,000 roentgens, respectively, were applied to the samples.

Data not contained in Table I indicate that sterility was usually obtained with the application of doses of less than 1×10^6 roentgens and was always obtained with doses of less than 1.7×10^6 to 2×10^6 roentgens.

Referring to Table II, it will be seen that from 92.3 to 99.997 per cent of the bacteria in the water and sewage samples were destroyed by the application of doses of cathode rays amounting to 100,000 r.e.p. and sterility was obtained by the application of doses of less than 1,000,000 r.e.p. in every case.

Discussion of Results

It is apparent from the foregoing that ionizing radiations, whether they be cathode rays or gamma rays, may

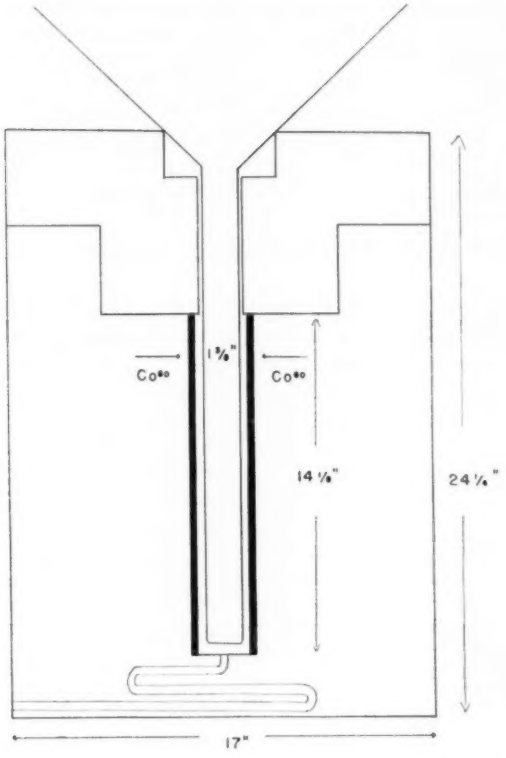

FIGURE 2.—General dimensions of lead pig container for Co^{60} irradiation source.

TABLE I.—Effect of Co^{60} on Water and Sewage Samples

Sample	Bacteria in Control (no./ml.)	Percentage Reduction in Bacteria per Ml. Due to Treatment with Co^{60} for		
		25 min.	50 min.	125 min.
Tap water (1)	30	93.4	96.7	96.7
Tap water (2)	43	88.5	90.5	95.4
River (1)	1,600	—	—	99.8
River (2)	77,000	99.97	99.99	99.999+
Swimming pool (outdoors)	570	88.3	94.4	99.7
Sewage (1)	13,000,000	—	99.997	99.999+
Sewage (2)	180,000,000	99.80	99.999+	99.999+
Sewage (3)	240,000,000	99.97	99.96	99.999+
Sewage (4)	11,500	90.4	97.2	99.9
Sewage (5)	25,000,000	99.95	99.97	99.993

TABLE II.—Effect of Cathode Radiation on Water and Sewage Samples

Sample	Bacteria in Control (no./ml.)	Percentage Reduction in Bacteria per Ml. Due to Irradiation with				
		100×10^3 r.e.p.	250×10^3 r.e.p.	500×10^3 r.e.p.	$1{,}000 \times 10^3$ r.e.p.	$2{,}000 \times 10^3$ r.e.p.
Deep well	13	92.31	100.00	100.00	100.00	100.00
Souhegan R.	600	98.33	99.69	99.85	100.00	100.00
Charles R.	1,600	99.75	99.94	99.94	100.00	100.00
Sewage	4,000,000	99.997	99.9997	99.9999+	100.00	100.00

[1] Irradiated at 3 megavolts; all samples treated in 10 sec. or less.

be employed either to substantially reduce the microbial content of water and sewage or to sterilize them.

The kilocurie Co^{60} source used in these laboratory experiments acts too slowly to be of practical importance in the terminal disinfection of water and sewage at the present time.

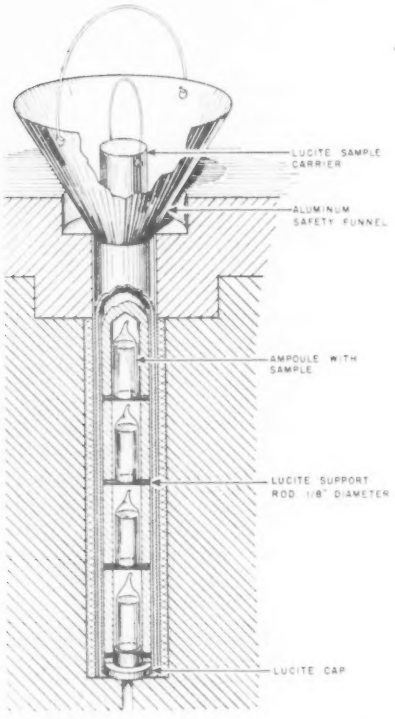

FIGURE 3.—Arrangement for irradiating samples with Co^{60}.

However, it is conceivable that should sufficient stockpiles of waste fission products, which Co^{60} simulates as a source of gamma radiation, become available, means could be provided for continuously circulating such fluids through long and circuitous paths with resultant and more rapid sterilization.

Cathode radiation provides a rapid and reliable method for purifying water and other products. Earlier work by Dunn and associates (4) supports this conclusion in respect to cathode radiations.

Conclusions

Water of low and high bacterial content and sewage samples containing millions of bacteria per milliliter may be sterilized by the ionizing radiations from Co^{60} and Van de Graaff cathode ray sources.

Acknowledgment

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STATISTICAL QUALITY CONTROL IN WASTE TREATMENT

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"There is no such thing as constancy in real life. There is, however, such a thing as a *constant-cause system*. The results produced by a constant-cause system vary, and in fact may vary over a wide band or a narrow band. They vary, but they exhibit an important feature called *stability*. Why apply the terms *constant* and *stability* to a cause system that produces results that vary? Because the same percentage of these varying results continues to fall between any given pair of limits hour after hour, day after day, so long as the constant-cause system continues to operate. It is the *distribution* of results that is constant or stable. When a manufacturing process behaves like a constant-cause system, producing inspection results that exhibit stability, it is said to be in *statistical control*. The control chart will tell you whether your process is in statistical control (1)."

Constant-Cause Systems

It has already been shown that the amount of pollutants in sewage and industrial wastes, and the treatment of such wastes, behave like constant-cause systems, by having normal frequency distribution. Velz (2) showed that the amount of suspended solids in raw sewage at Buffalo, N. Y., exhibited a normal frequency distribution for certain periods of time, as did the daily per cent reduction of suspended solids. Eckenfelder (3) showed that the oxygen demand rate of activated sludge treatment of cannery waste exhibited a normal frequency distribution. Halvorson (4) showed a bi-modal frequency distribution of pounds of B.O.D. per 1,000 lb. live weight in packinghouse wastes. This is an indication of more than one constant-cause system. Velz (2) also showed the existence of more than one constant-cause system or universe and how to differentiate between them. Fairall (5) has shown that the percentage of B.O.D. remaining in settled trickling filter effluent shows a normal frequency distribution for constant dosage rates.

When other trickling filter performance data are plotted on normal probability paper the frequency distribution is normal. The fraction of B.O.D. remaining in the settled (quiescent cylinder for 1 hr.) trickling filter effluent, n, as calculated from the data for the tests run on the Neosho, Mo., filters (6), is plotted in Figure 1. A summary of the pertinent data and statistical information is presented in Table I.

From Figure 1, it may be noted that the performance of the filter, as measured by the fraction of B.O.D. remaining, showed a normal frequency distribution, even with the variation in dosing rate. When similar data are plotted for the Coldwater, Ohio, milk waste treatment filter (7) the normal frequency distribution is observed.

Statistical Quality Control

In statistical quality control the average or mean value is designated as $\bar{X}$. The control limits are set up as $\bar{X} \pm 3\ \sigma_{\bar{x}}$, where $\sigma_{\bar{x}}$ is the standard error of the mean. If the distribution is roughly normal, approximately 0.27 per cent of the plotted data will fall

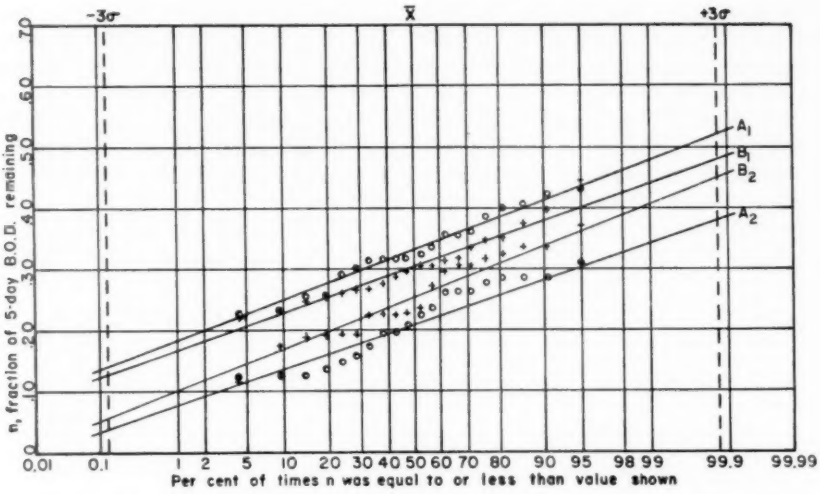

FIGURE 1.—Observed frequency of remaining B.O.D. fractions in Neosho, Mo., filter effluent.

outside the control limits. Under any and all circumstances less than 11.1 per cent of the plotted data will be outside the control limits. Therefore, if a point falls outside the 3 $\sigma_{\bar{x}}$ control limits, it can be said that the process is out of control statistically and there is an assignable cause for the variation; that this is not a constant-cause system. However, for points falling inside the limits—that is, while the process is in control statistically—it may only be said that, for practical purposes, it pays to act as if no assignable causes of variation are present. Many manufacturing operations are now operated on this basis (8). As long as the process is in control it is not economically worthwhile to hunt for causes of variation in the process.

Control Charts

The statistical quality control method of studying operating data is by means of control charts. Besides showing whether the distribution is normal and the value of the standard deviation for

TABLE I.—Summary of Neosho, Mo., Test Results

	Filter A		Filter B	
Date of test	3/19–4/11	7/12–8/3	3/19–4/11	7/12–8/3
Curve	A_1	A_2	B_1	B_2
Dosing rate[1] (m.g.a.d.):				
Average	17.1	13.2	13.1	16.8
Maximum	18.9	18.5	15.0	20.8
Minimum	15.4	7.9	11.7	12.7
Sewage temp. av. (°F.)	59.6	72.4	59.6	72.4
n, fraction of B.O.D. remaining	0.330	0.210	0.303	0.252
σ, standard deviation	0.065	0.059	0.059	0.068
Number of samples	20	20	20	20

[1] Daily average.

a group of data, the control chart can be used for evaluation of day to day operations. This can best be shown by an example.

The data for this example (Table II) are from the operation of a fixed nozzle trickling filter treating an industrial waste. It will be noted that samples were not reported for every day, which would have been desirable.

A 7-day moving total could be used to advantage in studying sewage treatment. In this example a 3-day moving total was used because three is the minimum subgroup size and the daily sampling was erratic, so that a 7-day average would not have any particular significance.

The data through January 17 were first tabulated and $\bar{X}$ and R calculated.

TABLE II.—Data for Example and Calculations

Date	V'/Q	C_r* (p.p.m.)	C_s† (p.p.m.)	B.O.D. Loading (lb./1,000 cu. ft.)	n‡	3-Day Moving Total§	3-Day Moving Av., $\bar{X}$**	3-Day Moving Range, R††	
Dec. 2	19.2	550	139	237	0.253	—	—	—	Dec. 2–Jan. 17:
3	17.9	576	183	266	0.317	—	—	—	
4	18.0	539	207	248	0.384	0.954	0.318	0.131	$\Sigma\bar{X} = 6.681$
5	17.1	532	199	256	0.374	1.075	0.365	0.067	
6	18.5	634	209	276	0.330	1.088	0.363	0.054	$\Sigma R = 1.505$
9	19.8	549	177	229	0.323	1.027	0.342	0.051	
10	18.7	659	144	290	0.219	0.872	0.290	0.111	$\bar{\bar{X}} = 0.238$
11	19.0	657	164	275	0.250	0.792	0.264	0.102	
12	18.4	633	161	284	0.254	0.723	0.241	0.035	$\bar{R} = 0.0536$
13	19.5	654	222	277	0.340	0.844	0.281	0.090	
16	18.5	546	124	246	0.227	0.821	0.274	0.113	Revised:
17	16.6	573	145	286	0.253	0.840	0.280	0.113	
18	16.9	630	158	308	0.251	0.731	0.244	0.026	$\Sigma\bar{X} = 4.569$
19	15.9	578	131	302	0.226	0.730	0.243	0.027	
20	16.4	583	123	296	0.211	0.688	0.229	0.040	$\bar{\bar{X}} = 0.228$
23	19.4	383	69	164	0.180	0.617	0.206	0.046	
24	17.1	542	104	262	0.192	0.583	0.188	0.031	
27	17.4	474	107	226	0.226	0.598	0.199	0.046	
30	19.8	368	69	154	0.188	0.606	0.202	0.038	
31	16.9	394	93	193	0.236	0.650	0.217	0.048	
Jan. 3	18.5	472	117	211	0.248	0.672	0.224	0.060	
6	18.7	413	—	183	—	—	—	—	
7	17.6	381	68	179	0.179	0.663	0.221	0.069	
8	17.1	584	112	282	0.192	0.619	0.206	0.069	
9	16.9	633	111	309	0.175	0.546	0.182	0.017	
10	16.6	515	90	357	0.175	0.542	0.180	0.017	
13	17.7	426	86	200	0.202	0.552	0.184	0.027	
14	16.8	495	88	250	0.178	0.555	0.185	0.027	
15	16.5	548	105	274	0.192	0.572	0.191	0.014	
16	16.4	560	98	283	0.175	0.545	0.182	0.017	
17	16.9	572	99	282	0.173	0.540	0.180	0.019	
20	18.1	515	55	237	0.107	0.455	0.151	0.068	
21	17.2	529	82	254	0.155	0.435	0.145	0.068	
22	16.8	641	118	316	0.184	0.446	0.138	0.077	
23	17.1	553	106	268	0.192	0.531	0.177	0.037	
24	17.5	815	100	386	0.123	0.499	0.166	0.069	
27	18.0	445	65	204	0.146	0.461	0.154	0.069	
28	16.9	535	84	263	0.157	0.426	0.142	0.034	
29	16.5	471	78	237	0.166	0.469	0.156	0.020	
30	17.3	—	77	—	—	—	—	—	
31	18.3	415	62	189	0.149	0.472	0.157	0.017	

TABLE II.—continued

Date	V'/Q	C_r* (p.p.m.)	C_t† (p.p.m.)	B.O.D. Loading (lb./1,000 cu. ft.)	n‡	3-Day Moving Total§	3-Day Moving Av., $\bar{X}$**	3-Day Moving Range, R††	
Feb. 3	21.4	—	66	—	—	—	—	—	Dec. 20–Feb. 28:
4	20.5	511	77	207	0.151	0.466	0.155	0.017	
5	19.0	718	167	314	0.232	0.532	0.177	0.083	$\Sigma R = 1.501$
6	18.2	479	68	218	0.142	0.525	0.175	0.090	
10	22.	—	92	—	—	—	—	—	$\bar{R} = 0.0416$
11	19.3	404	135	174	0.334	0.708	0.236	0.192	
12	19.7	468	86	197	0.185	0.660	0.220	0.192	$\Sigma\bar{X} = 6.820$
13	28.2	482	73	141	0.151	0.669	0.223	0.183	
14	19.9	—	91	—	—	—	—	—	$\bar{\bar{X}} = 0.175$
17	21.2	404	50	158	0.124	0.459	0.153	0.060	
18	20.2	365	46	150	0.126	0.401	0.134	0.027	Revised:
19	18.3	422	46	191	0.109	0.359	0.119	0.017	
20	18.5	318	42	142	0.132	0.367	0.122	0.017	$\Sigma\bar{X} = 5.102$
25	19.9	367	48	153	0.131	0.373	0.124	0.023	
26	18.4	347	57	156	0.164	0.427	0.142	0.033	$\bar{\bar{X}} = 0.170$
27	18.8	456	61	201	0.134	0.429	0.143	0.033	
28	18.8	534	57	234	0.107	0.405	0.135	0.057	
Mar. 3	19.6	330	33	140	0.100	0.341	0.114	0.034	
4	19.7	347	50	146	0.144	0.351	0.117	0.044	
5	18.6	390	39	174	0.100	0.344	0.115	0.044	
6	18.9	430	42	188	0.098	0.342	0.114	0.045	
10	20.6	394	124	158	0.315	0.513	0.171	0.317	
11	19.4	425	116	181	0.272	0.685	0.228	0.317	
12	18.0	452	125	208	0.276	0.863	0.288	0.043	
13	18.4	478	152	215	0.318	0.866	0.289	0.046	
17	21.7	283	38	108	0.134	0.728	0.242	0.184	
18	20.2	417	65	171	0.156	0.608	0.203	0.184	
19	20.5	359	48	145	0.133	0.423	0.141	0.023	
20	21.7	378	52	144	0.138	0.427	0.132	0.023	

* 5-Day B.O.D. in settled raw waste.
† 5-Day B.O.D. in clarified filter effluent.
‡ Fraction of B.O.D. remaining in the effluent.
§ Sum of values of n for the 3 consecutive samples.
** One-third of 3-day moving total.
†† Difference between maximum and minimum values of n for the 3 consecutive days.

At least 25 subgroups should be used. In this example 28 subgroups were used. The averages ($\bar{\bar{X}}$ and $\bar{R}$) of the $\bar{X}$ and R values were calculated next for the 28 subgroups, and the upper and lower control limits calculated from

$$\mathrm{UCL}_{\bar{X}} = \bar{\bar{X}} + A_2\,\bar{R}$$
$$\mathrm{LCL}_{\bar{X}} = \bar{\bar{X}} - A_2\,\bar{R}$$
$$\mathrm{UCL}_{R} = D_4\,\bar{R}$$
$$\mathrm{LCL}_{R} = D_3\,\bar{R}$$

Substituting the factors obtained from Table III (8) gives

TABLE III.—Factors for Determining, from $\bar{R}$, the 3σ Control Limits for $\bar{X}$ and R Charts (8)

Number of Observations in Subgroup	A_2	D_3	D_4
2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0.08	2.00
7	0.42	0.14	1.92

$\mathrm{UCL}_{\bar{X}} = 0.238 + (1.02)(0.0536) = 0.293$
$\mathrm{LCL}_{\bar{X}} = 0.238 - (1.02)(0.536) = 0.183$
$\mathrm{UCL}_{\bar{R}} = (2.57)(0.0536) = 0.138$
$\mathrm{LCL}_{\bar{R}} = 0.0$

All of the values of R are within limits, but the values for $\bar{X}$ on December 4, 5, 6, and 9, and on January 9, 10, 16, and 17, are outside the control limits. Eliminating these values for $\bar{X}$, a new value for $\bar{\bar{X}}$ (average value of $\bar{X}$) is calculated. There now are only 20 subgroups used in calculating $\bar{\bar{X}}$. It would have been more desirable to start with enough subgroups to have at least 25 left after eliminating the out of control points. The revised limits of $\bar{X}$ are, therefore:

$$\text{UCL}_{\bar{X}} = 0.283$$
$$\text{LCL}_{\bar{X}} = 0.173$$

Using these control limits, all data are plotted on Figure 2.

Stopping to consider the values plotted through January 17, the out of control values of $\bar{X}$ calculated to December 10 may be accounted for by the fact that on December 2 the practice of returning the secondary sludge to the primary clarifier was discontinued and all clarifier sludge was pumped directly to the digester. It had been noted that some ponding was taking place on the filter and about this time rodding and excavation of the ponded areas was undertaken. This latter effort may account for the consistent low values starting with December 20.

Assuming for the example that the limits are established, the recording is continued starting with January 20 and plotted daily as the analyses are reported.

By the end of January it is apparent that the constant-cause system assumed from the data for Dec. 4–Jan. 17 has been superseded. Maybe the elimination of the ponding was benefiting the performance, or the loading, either volumetric (V'/Q) or organic, was affecting the operation. Since the fraction remaining is not increasing it appears desirable to plot the data for a while and establish new control limits.

When the averages for February 11, 12, and 13 were plotted it should have been immediately noted that something was definitely causing poor operation, not so much from the values for $\bar{X}$, but because the values of R were far out of line. It an actual case the reason for this out of control operation should have been found.

By the end of February it appears desirable to establish new limits, based on data from December 20, except for the out of control range values for February 11, 12, and 13. Thus, $\text{UCL}_{\bar{R}} = 0.107$.

It is noted that all values of R are in control except the three in February. Next a new value for $\bar{\bar{X}}$ is determined for all 39 subgroups from December 20 through February 28, as follows: $\text{UCL}_{\bar{X}} = 0.218$; $\text{LCL}_{\bar{X}} = 0.132$.

The values for $\bar{X}$ for December 20, January 3 and 7, and February 11, 12, 13, 19, 20, and 25 are out of statistical control and are eliminated, a revised value of $\bar{\bar{X}}$ being determined for the remaining 30 subgroups, as follows: $\text{UCL}_{\bar{X}} = 0.213$; $\text{LCL}_{\bar{X}} = 0.127$.

The new limits are narrower for both R and $\bar{X}$, but this is based on past experience with the filter and from the statistical quality control viewpoint, any results outside the limits are caused by some factor other than chance. Likewise, results within the control limits are to be expected from chance and it is considered good practice not to hunt for causes in variations as long as the plotted values are within control. The three points for $\bar{X}$ below the lower control limit for February 19, 20, and 25 are largely due to the value of n for February 19. This might be a sampling error.

As the values of $\bar{X}$ are plotted for March, out of control performance is indicated by the out of limits values for $\bar{X}$ and R. Again, in an actual case immediate action should have been taken to account for or correct the cause.

In Figure 2 the values for V'/Q and the B.O.D. loading are also plotted in order to consider them as causes for the out of control variations in perform-

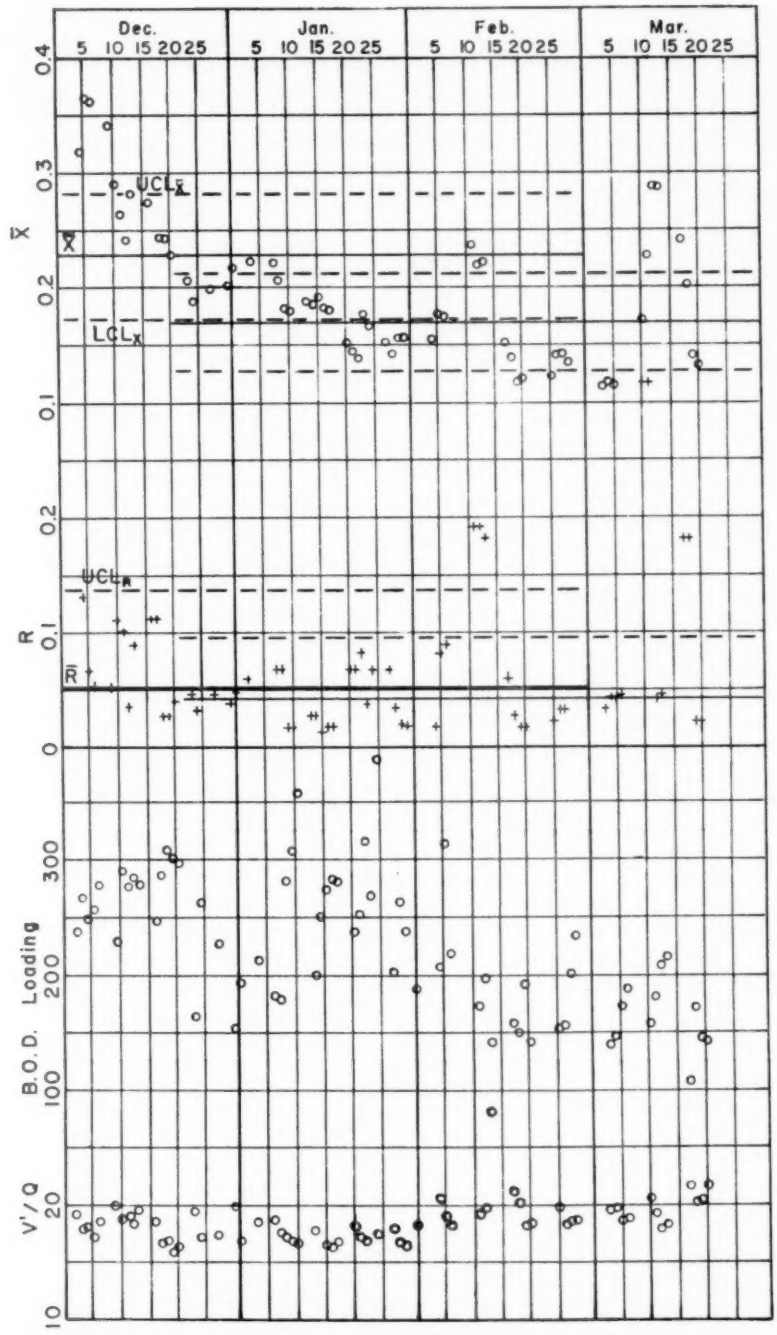

FIGURE 2.—Plot of illustrative data, showing $\bar{X}$ and R charts, B.O.D. loading, and V'/Q loading.

ance. The value V'/Q is the cubic feet of media per 1,000 gal. of waste flow per day. It is inversely proportional to n, the fraction of B.O.D. remaining. The B.O.D. loading in pounds of 5-day B.O.D. per 1,000 cu. ft. of media is proportional to n. In comparing loadings with performance it should be remembered that $\bar{X}$, the average values of n, are plotted for the last day used in figuring the 3-day average.

In general it may be noted that while both the B.O.D. loading and $\bar{X}$ show a general trend downward to the right, the heavy loadings in January and early February correspond with relatively low values for $\bar{X}$, and some of the low loadings in March correspond with the out of control situation for $\bar{X}$ during that month. The general trend for V'/Q is upward to the right, inversely proportional to $\bar{X}$, as might be expected. The values for V'/Q were relatively constant in January when filter performance was in better control statistically. Neither V'/Q nor the B.O.D. loading appear to closely affect the filter performance.

This example is not the best for exhibiting the use of statistical quality control, but it is probably characteristic of data generally available. If such control is to be employed, the sampling routine would undoubtedly be improved and possibly would not have such an erratic effect on the control charts. It is hoped that this example will encourage the use of statistical quality control in waste treatment works.

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MODERN MATERIALS AND METHODS FOR JOINING SEWER PIPE*

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A wide variety of pipe materials have been proposed for transporting sewage and industrial wastes. Since it is impractical to construct a jointless line, however, the effectiveness of a system consisting of the most nearly perfect pipe is dependent entirely on the quality of its joints. Pipe quality is controlled by the pipe manufacturer, but joint efficiency of even the best jointing material depends, to a large extent, on installation methods. Hence, the importance of up-to-date information on materials and methods for joining sewer or industrial waste lines cannot be over-estimated.

Cast iron, silicon-iron alloys, asbestos-cement compositions, concrete, fiber-filled asphalts, asbestos-filled thermosetting plastics, and vitrified clay pipe have been used successfully for waste lines. Less resistant materials protected by rubber or plastic linings also have been investigated. Since vitrified clay makes the most widely used chemically resistant pipe, this discussion is restricted to this type of pipe. Obviously, much of the information presented can also be applied to other types of pipe.

Although many attempts have been made to use specially designed precast joints and trowelable jointing compositions, most vitrified clay pipe sewer lines consist of short sections of bell and spigot pipe joined with hot-poured materials. There are more than 100 patents on various methods for joining pipe, but this paper is restricted to a discussion of the most widely used types of jointing materials.

Pipe Joint Specifications

A perfect pipe joint should have the following properties:

1. Simplified directions for use.
2. Foolproof and rapid installation procedures to permit early use of the line.
3. Freedom from toxic or soluble components, porosity, or other imperfections.
4. Permanent bond to the pipe under all normal service conditions.
5. High resistance to infiltration and exfiltration.
6. Complete resistance to normal household wastes, cleaners, detergents, greases, and normal soil conditions.
7. Sufficient flexibility to permit normal movement of the pipeline resulting from settling, etc.
8. Sufficient strength to resist breaking of the joint in the trench.
9. Retain its original properties during long periods of service.
10. Resistance to slumping.
11. Resistance to cracking under normal underground service conditions.
12. Resistance to penetration by roots.
13. Economical advantages.

A completely foolproof pipe joint has yet to be perfected. Nevertheless, as will be evident from the subsequent description, several satisfactory sewer jointing materials are available commercially.

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Hot-Poured Filled Asphalt Joints

The oldest and best known hot-poured joint is a filled asphaltic compound developed about 50 years ago. Compounds of this type are usually composed of equal parts by weight of properly graded fillers and specially prepared asphalts. These products have a specific gravity of about 1.5, an A.S.T.M. penetration of about 12 throughout the entire temperature range expected in actual service (32° to 115° F.), and a ball and ring softening point of about 225° F. Federal specifications have been written covering this type of product.

Priming of bells and spigots prior to hot pouring is advisable and is essential if the joints are constructed under wet conditions. In all cases, it is important that the bell and spigot surfaces be clean and dry and that the annular space be yarned with clean dry jute. Two or more pipes may be joined on the bank while in a vertical position; in this case, the hot compound is poured in the absence of an asbestos runner. A runner, of course, must be used for all joints poured in the trench.

When hot-poured asphaltic compositions are heated with stirring at 400° to 450° F., they flow freely (Figure 1). They should be ladled out while heated within this range and the joint should be filled in one pouring. The quantities of both jute and compound will vary with the type and size of pipe used. An estimate of quantities can be secured by multiplying the volume of the annular space in cubic inches by 0.056 to determine the weight in pounds of the compound required for each joint. Slide charts and tables are available for determining quantities required for various standard-size pipes.

A properly poured bituminous joint has good adhesion; is strong, dense, and chemically inert; has some flexibility; solidifies quickly; will deflect without breaking the joint or the pipe; and is economical and easy to use. Properly poured filled asphaltic type joints have displaced hydraulic cement mortar joints almost completely and have proved to be satisfactory over a period of years in many different geographical locations.

Filled Plasticized Sulfur Compositions

Sulfur compound joints have been used widely for joining vitrified clay pipe. These materials are more root resistant and less flexible than the asphaltic types. Improved sulfur compounds contain a bactericide in sufficient quantities to prevent attack by sulfur bacteria.

Acceptable sulfur compounds should contain at least 55 per cent sulfur, 35 per cent graded silica aggregate, sufficient bactericide to prevent attack, and enough plasticizers to yield a permanently ductile joint. A typical sulfur joint has a tensile strength of about 500 p.s.i., and a compressive strength of approximately 5,000 p.s.i. The material should flow as freely as water when heated, but the filler should not settle out when the product is in the molten condition. Federal specifications for satisfactory sulfur compositions have been published and tentative A.S.T.M. specifications are available.

Filled Coal Tar Pitch Joints

A hot-poured jointing material based on filled coal tar pitch is also available. Despite claims made for superior root resistance for this type of product, adhesion to the pipe surfaces is often poor. This permits roots to grow at the interface between the compound and the pipe. Even in the absence of root growth, infiltration can take place at this interface.

Some difficulties have been experienced in the field with coal tar compositions due to the escape of volatiles during melting. This deficiency has been overcome in part through the use of covered pots and through the intro-

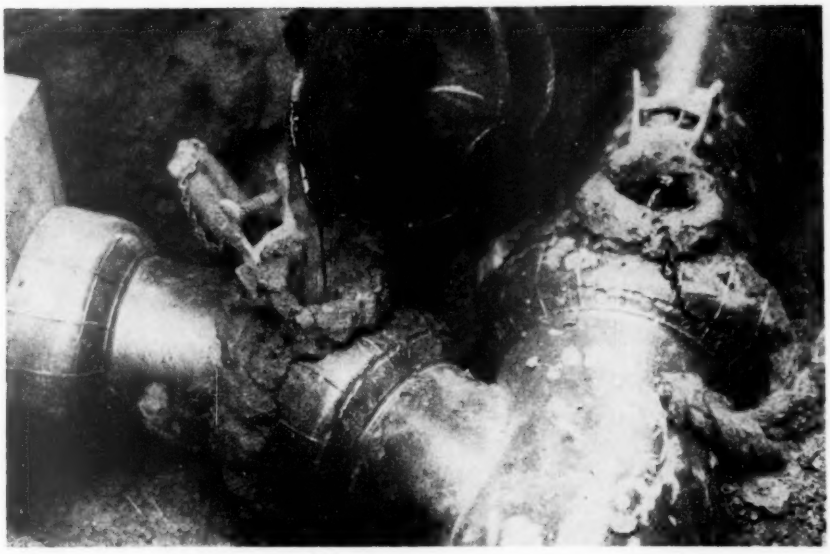

FIGURE 1.—Pouring a hot-filled asphalt joint.

duction of a gel-type coal tar product. The gel-type product has poorer adhesion than the harder composition, but has been recommended for specific applications.

A typical filled coal tar pitch composition will have a tensile strength of approximately 250 p.s.i., and A.S.T.M. penetration of less than 1 throughout the entire anticipated temperature range, a ball and ring melting point of 195° F., and a specific gravity of 1.5. The coal tar pitch content is usually greater than 70 per cent of the entire composition.

Hot-Poured Filled Plastic Joints

Another widely used jointing material is based on a hydrocarbon plastic that has outstanding root resistance and excellent adhesion to ceramic surfaces. This product does not lose adhesion, even when soaked in water for long periods of time. A large number of long-term tests made in various parts of the country have shown this product to be completely resistant to a wide variety of plant roots.

Unlike asphalt and coal tar products, the hot plastic melt (Figure 2) is not affected adversely by long-term heating in the melting pot. The filler in this product does not settle in the melting pot and the melt is not readily ignited when heated under field conditions. This product has low shrinkage and outstanding chemical resistance.

A typical hot-melt plastic jointing material contains approximately 40 per cent hydrocarbon plastic and 60 per cent graded filler. The specific gravity of this material is approximately 1.7 and the softening point is about 215° F. The A.S.T.M. penetration of this material is usually less than 1 throughout the entire range expected under service conditions. The adhesion to primed unglazed vitrified clay pipe is greater than 200 p.s.i., even after the joint has been soaked in water for long periods of time.

As in the case of filled asphalt and coal tar compositions, priming of the bell and spigot surfaces is recommended for all installations and is es-

FIGURE 2.—Pouring a hot-filled plastic joint under wet conditions.

sential when the joints are made under wet trench conditions. This plastic product is slightly more expensive than filled asphalt or coal tar pitch, but its properties are closer to the specifications for a perfect pipe joint than any other known commercial material.

Precast Asphaltic Joints

High-melting asphalt-type joints are also precast and used as rings on both the bell and the spigot. The asphaltic surfaces to be joined are painted with a solvent just before the pipe is placed in position in order to secure a monolithic joint. This type of joint can be laid faster than many other types and can be installed under the most adverse conditions. In spite of the simplicity of the operation, it is sometimes difficult to secure good joints due to the irregularities in the pipe and damage of the collars on the spigot end during storage and transportation.

A slipjoint type asphaltic composition is most satisfactory on large jobs when the shape and size of the pipe is fairly uniform. The filled asphaltic compositions used in this type of joint usually have a ball and ring softening point of at least 240° F., a penetration of between 5 and 10, and a specific gravity of 1.5.

Neat Cement Joints

Other commonly used jointing materials consist of neat cement and other trowelable compositions. Both are used with vitrified clay pipe and require expert workmanship. Infiltration and root penetration of the rigid neat cement joints can be prevented through the use of a metal collar, such as a Weston gasket. The metal form is left on the pipe permanently when cement joints are constructed in this manner.

Ready-Mixed Trowelable Compositions

Trowelable compositions based on asphalt and synthetic rubber have been used, particularly with tongue and grooved concrete pipe. These products

set by evaporation of solvents; hence, they do not harden under water. Good joints with trowelable compositions are obtained only through the use of top-quality workmanship. The tendency to leave the bottom section of the annular space unfilled can be overcome in part by troweling in a bead of the material on the bottom two-thirds of the bell interior before shoving the pipe home.

A typical trowelable asphaltic material (Figure 3) contains approximately 50 per cent filler, of which at least 35 per cent is asbestos fiber. It has a specific gravity of 1.3 and is completely resistant to normal sewage wastes. It should harden uniformly and not form a surface skin.

A typical filled synthetic rubber composition contains at least 50 per cent filler, of which at least 5 per cent is asbestos. It has a specific gravity of 1.1 and is completely resistant to normal sewage. It should contain at least 10 per cent synthetic rubber and have outstanding adhesion and flexibility.

On-the-Job Mixed Troweling Compositions

On-the-job mixed compositions possess the previously cited shortcomings of all troweling compounds and, in addition, require good field supervision of the mixing operation. Usually, about three parts of powder is added to one part by weight of liquid with thorough stirring in order to secure an intimate uniform mixture. Slight variations in the ratio of powder to liquid may be made, but large variations will produce unsatisfactory joints.

A typical troweling composition of this type has a specific gravity of 1.4. It should not be gritty but should yield a cohesive mass that will set even under water to form a joint that is completely resistant to normal sewage.

FIGURE 3.—Application of a ready-mixed troweling composition to a tongue and groove pipe.

FIGURE 4.—Application of fillet of infusible chemical resistant cement in the construction of a chemical resistant joint.

Chemical Resistant Joints

None of the joints described previously is recommended for service in the presence of solvents or elevated temperatures. Joints based on a combination of furane and sulfur cements, however, are satisfactory for most industrial waste lines, even at elevated temperatures.

In this construction, the more economical sulfur cement is used essentially in the same manner described previously for other hot-poured jointing materials. It fills the main portion of the annular space, but the effectiveness of the joint depends primarily on the presence of a continuous fillet of the more expensive furane cement which is in contact with the effluent.

The furane cement mortar is prepared by mixing approximately two parts of powder with one part by weight of furane liquid resin and the resulting mortar is troweled in the portion of the annular space coming in contact with the industrial wastes (Figure 4). Furane cements are unaffected by alkalies, salts, solvents, and most acids, even at temperatures of 350° F. They are attacked by nitric, chromic, and concentrated sulfuric acids.

There are several modifications of this joint, but all successful variations consist of an infusible resin cement in contact with the effluent with the major portion of the annular space filled with a less expensive hot-poured material (Figure 5).

Tubular Joint

One of the recent novel joint developments consists of a deflated tube having essentially the same dimensions as the annular space between the bell and spigot. This tube is inserted in the annular space and then filled with a quick-setting hydraulic cement. Although this joint is somewhat expensive, it can be constructed readily even under adverse conditions.

Vinyl Plastisol Joint

Another recently developed joint makes use of a vinyl plastisol, which is

hot-molded in place as a threaded ring on clay pipe. The flexible threaded sections are then joined with a corresponding hard molded phenolic plastic threaded ring.

Straight End Pipe

A large number of the jointing methods that have been patented are based on the use of straight end pipe. However, few of these inventions have been reduced to large-scale commercial use. One of the simplest and possibly the most practical device consists of a simple collar containing a hole for the introduction of hot-poured asphaltic or plastic material. As might be expected, considerable ingenuity and "gadgeteering" has been displayed in order to fulfill the obvious requirement that the hot-poured material must not enter the pipe itself nor flow out of either end of the sleeve. Continued progress is being made in the solution of this inherent problem.

Conclusion

Because of the wide variety of pipe materials and jointing methods available, it might be concluded that it is impossible to make recommendations for specific installations. Nevertheless, although all previously described materials and methods may be used, the following recommendations may be used as a guide:

For domestic sewage in locations where root resistance is not important, vitrified clay pipe joined by hot-poured filled asphalt joints should be used.

For domestic sewage in locations where root resistance is essential and where good adhesion to the pipe is imperative, a hot-poured filled plastic joint should be used.

Either of these recommendations is

FIGURE 5.—Pouring plasticized sulfur cement in a multiple line consisting of vitrified clay pipe and chemical resistant joints.

satisfactory for cold industrial wastes in the absence of water immiscible solvents, but a combination joint consisting of an infusible furane and a plasticized sulfur cement is recommended whenever solvents or warm industrial wastes are present.

In spite of these recommendations, large quantities of other pipe materials and jointing methods will be used. New developments are being announced almost daily: today's recommendations may be subject to revisions a few years from now. In addition, there is no reliable substitute for experience. If the present methods being used by any specific plant or municipality produce perfect waste lines, it is not recommended that the methods of construction be changed. However, it is suggested that when difficulties relative to the joining of pipe are encountered, the previously cited recommendations be considered.

UNDERWATER SEWER INSTALLATION EXPEDITED

Steel strapping reduced diver and crew time by 75 per cent and hastened the underwater installation of a 500-ft. sewer outlet in Lake Washington, near Seattle, Wash. By fastening concrete pipe to 6-in. by 8-in. fir timbers, the McCray Marine Construction Co., Seattle, easily completed the installation, which required placing some sections as much as 40 ft. below the water's surface.

Rather than lay one 4-ft. length of concrete pipe at a time, the company strapped five lengths to each of several 20-ft. timbers (Figure 1), placed them on a barge, and hauled them to the installation site. There, each section was lowered by a winch, guided into place by the diver, and joined to previously positioned sections. This method made the jointing and laying problem much easier for the crew and minimized the diver's underwater time.

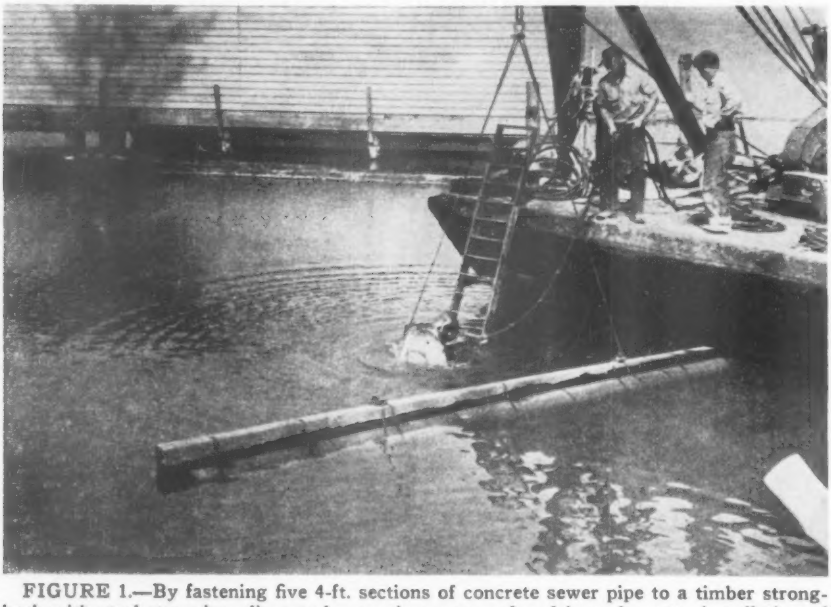

FIGURE 1.—By fastening five 4-ft. sections of concrete sewer pipe to a timber strongback with steel strapping, diver and crew time were reduced in underwater installation of a sewer outlet.

AGRICULTURAL VALUES OF SEWAGE

By Bernard P. Skulte

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Cultivated plants require for their growth a good mellow top soil containing humus and moisture, a certain amount of nutrients, sunlight, and air. Climate plays an important part and good tillage takes care of the soil. The Law of the Minimum determines the outcome of the crop (that is, if chemicals, moisture, air, or organic matter are deficient they have to be replaced).

Fertility of the soil is rapidly destroyed by cultivation and soil becomes less productive as some of these elements decrease. Every time a crop matures and is harvested certain of the tissue-building substances are removed from the land. Through negligence of man most of these elements never get back to the land in such places and forms that they can be made available as future plant food. This process is almost automatically accelerated by the growth of modern civilization, and reaches its culmination in many great cities where millions of dollars' worth of irreplaceable plant nutrients, after varying degrees of treatment, are annually drained down through the sewers to oceans—to be lost to the land.

Sewage as applied to land has a fourfold value, for it contains the major fertilizing elements and micro-nutrients (trace elements), organic matter, and water.

Nutrients

Soil usually contains nearly a sufficient amount of the different elements, with the exception of nitrogen, phosphorus, potassium, and lime. It is these and some trace elements that are chiefly required in fertilizers employed to improve soils so that they will produce better plants. Commercial fertilizers supply these elements, but lack the soil conditioners composed of decayed organic matter. Without sufficient organic matter in the soil, commercial fertilizers might be applied liberally and yet not produce any appreciable effect upon the crop. In such cases, in fact, commercial fertilizers may do more harm than good.

Nitrogen

Nitrogen is one of the elements most largely used by growing plants, because its compounds form the protoplasm—the living part—of the cells. Nitrogen stimulates the growth of leaf and stem. Lack of it causes a stunted, sickly plant growth. Living organisms in the soil require nitrogen for the building of their own tissue and in the production of enzymic materials. Many bacteria satisfy their nitrogen requirements from ammonia-nitrogen.

Ordinary domestic sewage contains from 15 to 35 p.p.m. of nitrogen, nearly half of it being in the form of ammonium salts and the remainder in the form of organic nitrogenous compounds. The latter are not stable forms, but are decomposed to ammonia by hydrolytic and oxidative mechanisms of numerous heterotrophic microorganisms. Ammonia in turn is converted by aerobic autotrophic bacteria, in the presence of oxygen, into nitrites and nitrates (in two stages). The young plants can utilize nitrogen only in the form of nitrates, because their molecules are smaller than those of ammonia. Therefore, the first dosing of sewage should be applied early in spring so that the nitrogen becomes

FIGURE 1.—Fields irrigated with sewage at Coesfeld-Westfalen, Germany, showing concrete-lined main channel with outlets to laterals.

fully available to crops during the growing season. Later, with the abundant foliage and greater suction of sap, the plants also can acquire nitrogen in the form of ammonia and sewage can be applied by overhead irrigation. Nitrates are utilized by plants or removed by drainage, ammonia is absorbed by clay and humus particles. According to Kreuz (1) the plants utilize 75 per cent of sewage nitrogen.

Phosphorus

Phosphorus increases root development, strengthens straw, enhances seed formation, hastens ripening, improves vegetables and grass, and makes plants more resistant to disease. Sewage contains from 4 to 9 p.p.m. of phosphorus, with an average of 5 p.p.m., partly as phosphoric compound, the rest as salt, which in the soil changes into acid phosphate. The latter is directly utilized by plant roots or absorbed by mineral and humus particles. There is not much leaching. Counting the loss by sedimentation in sludge, the utilization of phosphorus is estimated at 80 per cent (2).

Potassium

Potassium is a necessary component of chlorophyl and is required for formation of starch, sugar, cellulose, and other carbohydrates, enabling the plants to combine carbon, hydrogen, and oxygen supplied by carbon dioxide and water. Potash is an important factor for vigorous growth and increases resistance to disease. Sewage contains from 10 to 20 p.p.m. of potash, mostly in solution. Little potash is removed by drainage, most of it is exchanged by sodium chloride. Soil colloids (that is, clay and humus) have a high capacity of base exchange. They adsorb the cations, such as potassium, calcium, and magnesium, upon their surfaces. Although these adsorbed cations are chemically combined with the colloid, they may be replaced by other stronger cations occurring in

soil solution and so made available to plants. Sodium may be the predominant cation in sewage effluent. Part of the potash is used by plants, but excessive quantities of it tend to prolong the season of growth and thus delay the maturing of the crop. The rest of the potash is absorbed by soil colloids or lost through leaching. According to Lacour (2) plants utilize 60 per cent of sewage potassium.

Lime

Calcium is an indirect fertilizer that neutralizes acidity and checks some plant diseases. Soils high in organic matter, such as muck and peat, are generally deficient in calcium. So, also, are sandy and clayey soils. Calcium in sewage exists in the form of carbonate, which is favorable to important soil organisms. But lime does not accumulate in the soil. It is removed by crops and microorganisms, and the rest leaches away. Occasional replenishing is required to maintain proper condition of the soil.

Nutrient Need

The amounts of each element delivered in sewage per capita per year are as follows:

Nitrogen	7.5 to 8.5 lb.
Phosphorus	2.0 to 2.5 lb.
Potash	4.0 to 6.0 lb.

Considering the loss by mechanical sedimentation and the utilization factors previously given, the following are available for plant use:

Nitrogen	4.0 lb.
Phosphorus	2.0 lb.
Potassium	3.0 lb.

The amounts of each element required depend on the soil, the climatic conditions, and the crop. Various formulas are suggested by agricultural authorities for the combinations of major fertilizing elements best suited to different crops and soils. For mixed crops, an average per-acre requirement is 80 lb. of nitrogen, 45 lb. of phosphorus, and 70 lb. of potash. Accordingly the number of persons needed to supply the required nutrients, by sewage, is as follows:

Nitrogen	20 persons per acre
Phosphorus	23 persons per acre
Potash	23 persons per acre

If only grass or similar cattle fodder is raised the contributory population may be doubled.

This means that average applications of 2,300 and 4,600 g.p.a.d. may be practicable for irrigation of cropland and grassland, respectively, or amounts equal to about 2.0 and 4.0 ft. of effluent irrigation per unit area per year. There is no reason to operate sewage farms at much higher rates of forced irrigation, because septic conditions are liable to result. When the actual field test indicates the need for any particular additional nutrients, they must be supplied by commercial fertilizer. Generally, however, the latter are effective only when water, humus, and lime are present in the soil, in proper amounts. Biologically, continuous fertilization, as exemplified by sewage farming, is better than periodic fertilization. But the raising of crops conditions the soil for continued waste disposal purposes.

Trace Elements

Minute quantities of certain chemical fertilizing elements and growth promoting substances are essential to the normal growth of plants. Sewage contains sulfur, magnesium, iron, iodine, sodium, boron, manganese, copper, and zinc in easily soluble form as vitamins and hormones, besides other trace elements. Only recently, specialists have discovered the importance of vitamins and hormones in plant food. All these micro-nutrients have the ability to produce interesting changes, such as root development, stem elongation, cell swelling, ripening of fruit, etc., in growing plants. For example, without small amounts of iron,

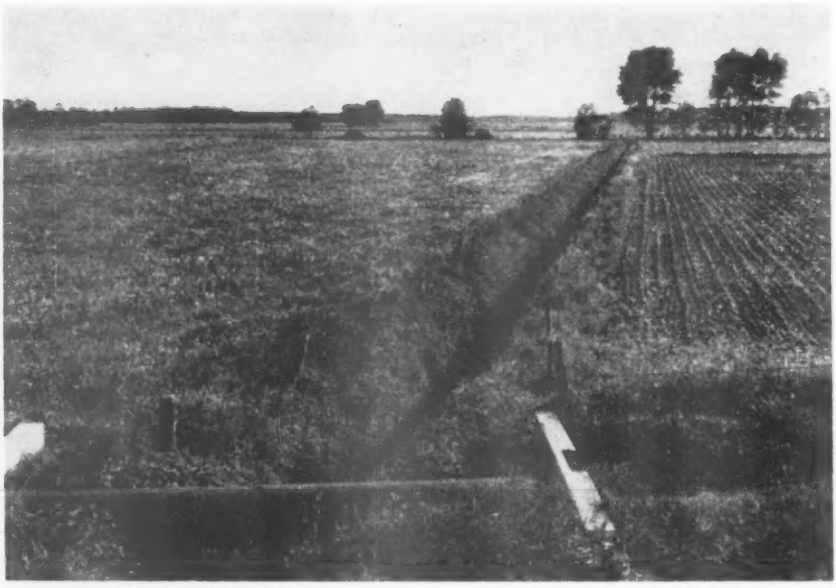

FIGURE 2.—Land treatment of sewage in Coesfeld-Westfalen, Germany, showing distribution conduit over drainage ditch.

plants develop no green color, whether they have direct sunlight or not. Chlorophyl cannot be formed without it, therefore no plant growth results. The action of magnesium in plants is not very well understood, but it is known that it is indispensable. Small but definite amounts of boron must be available, either from irrigation water or soil, in order to obtain good growth of crops; but toxic effects will occur if more than traces are present.

Sodium is of little importance as a plant food, but assists in chemical changes which take place in the soil, and may aid in nitrification. In soils rich in clay and humus, sodium cation liberates certain plant nutrients, including calcium, magnesium, potassium, and phosphorus. The structure of the soil is improved by the addition of small quantities of sodium. In light soils, sodium tends to hold moisture and aid capillary attraction. A little sodium chloride reduces the amount of potash required by root crops. The soluble sodium percentage of sewage effluent is an important index of its suitability for irrigation. Effluent containing a "sodium percentage" above 65 per cent is considered of poor quality, 50 to 65 per cent is of questionable quality, and below 50 per cent is good for application to soils (8). Almost all micro-nutrients play a dual role—as an essential element and as a toxic element—in plant food. Therefore, they should always be accounted for in water analyses. On the basis of studies by agriculturists and soil scientists Stone *et al.* (10) have determined the generally accepted permissible concentrations for various chemical constituents in irrigation waters for various types of soils and crops.

Humus

Humus is soil organic matter that has undergone decay to such an extent that it has lost its identity. According to Waksman (3), humus is in a dynamic condition, as it is constantly

formed from plant and animal residues and is continuously decomposed further by microorganisms. Humus contains almost all major and minor plant nutrients, and its colloids have the property of adsorbing the soluble nutrients, thus preserving them from loss through leaching. McGeorge (5) found that the base exchange capacity of soils was directly related to the organic matter content. Ingols (4) designates organic matter as the causative agent in the adsorption of ammonia.

Therefore, humus is one of the most important agricultural constituents of the soil. By its colloidal nature, it not only improves the physical condition of the soil, but it also enables the soil to absorb and hold the moisture. Thus, plant food is held in storage and soil life is enriched. In addition, soils rich with humus withstand erosion. Furthermore, decaying organic matter produces carbon dioxide and other products that are solvents of mineral matter in soil, thus making them available to plants, as well as supplying the carbon dioxide that is used directly by plant leaves. Unfortunately the quantity of humus, this top-soil capital, has rapidly declined over the last 50 years. According to Pfeiffer (6), the organic matter in American soils, on the average, has run dangerously low (around 1.5 per cent), although the original soil had from 4 to 6 per cent of humus. Even in skillfully managed soils, humus slowly disappears and the supply has to be maintained and increased.

Sewage has less organic matter than manure, but it is in the form of mild humus easily convertible into plant food by bacteria, fungi, algae, protozoa, worms, snails, and insects. When sewage is applied to the soil the biological matrix develops, largely in the upper strata of the soil, with a mat on the surface of soil particles. The air in the interstices of the soil provides the necessary oxygen for the aerobic bacteria. Some of the microorganisms, such as algae, occasionally increase the available oxygen. Generally, sewage is immediately useable by plants; it does not undergo gradual change during several months, as in "well-rotted" material, such as manure. On the contrary, it looses a great deal of its fertility when utilization is delayed.

Humus serves as a source of energy for the development of various groups of microorganisms, and during the process of decomposition gives off a continuous stream of carbon dioxide and ammonia, upon which plant life depends. The amount of carbon dioxide produced determines the value of humus fertilizer. According to Zunker (7), 1 g. of raw sewage organic matter in 24 hr. produces 9.5 c.c. of carbon dioxide, whereas the same quantity of organic material from primary effluent, secondary effluent, sludge, manure, and compost produces, respectively, 8.3, 7.0, 2.3 to 2.6, 1.2 to 2.5, and 0.07 to 0.2 c.c. of carbon dioxide.

With increasing age of the organic matter, carbon dioxide production decreases in nearly logarithmic proportion, except in the case of compost, which remains stable for a longer time. For the conversion of organic matter bacteria need sufficient oxygen. Otherwise they starve, as most of them starve when the pH of the soil becomes less than 5.8. Therefore, the pore space must be kept in contact with atmosphere so that the gaseous oxygen present in the air can follow the percolating waters down into the soil. Sewage must be applied to land intermittently; rest periods must be provided. A dry or completely saturated soil environment is not favorable for the growth of soil microorganisms, but the alternate dry and wet cycles provide the optimum condition. For alkalization of soil sufficient lime has to be supplied. On the other hand, too large and too frequent applications of calcium compounds will cause decompo-

sition of humus faster than it can be used by the plants, resulting in loss from leaching.

Water

Growing plants are composed largely of water. From 60 to more than 90 per cent of the green weight of staple crops is water. Most of this water is taken from the soil and contains the food which passes up to the leaves, where it is digested, the surplus water being passed off as transpiration into the atmosphere. In addition, a considerable amount of soil moisture must evaporate and drain away before there will be sufficient air in the soil. The nitrates formed in the upper strata are washed down by water, where they are then made available for the deep roots of the plants. Solids have to be dissolved in water before they can enter plants to be utilized for growth.

There is a shortage of water in the United States, however, and not only in the southern states. It is abundant only in a small part of the country, in the so-called "evergreen" Pacific Northwest. Further, the rainfall diminishes to the scarcity of the arid Southwest, where the deficiency in water supply is becoming critical. In many localities overpumping has caused an alarming lowering of the ground-water table. Streams which once flowed in considerable volume have disappeared. From facts gathered from 29,000 wells the U. S. Bureau of Soils (Bull. 92) shows a marked fall in the water level. But in any one region the recorded total precipitation varies widely from season to season and from year to year. Furthermore, rainfall usually is irregular. Even in well-watered areas, a period of two weeks without rain may be serious, especially in the growing season.

Successful cultivation of the soil necessitates an ample supply of water. The capillary water reserves cannot long provide the best soil moisture conditions for maximum growth of crops. Consequently that part of the rainfall which infiltrates into the soil becomes a most critical matter in many localities, because deficiencies of soil moisture are replenished before water percolates through the various soil levels into the ground-water table. Normally little, if any, water percolates into the ground-water storage during a growing season because of the demands of vegetation.

Rainfall is inadequate to supply the enormous quantities of water involved in the natural processes of evaporation, transpiration, and evaporation by capillary action in the soil in addition to surface runoff and the requirements of cities and industries. In many areas industrial expansion cannot take place because of the limited supply of water.

The same water problem that concerns agriculture and industry also threatens domestic use of water. Nearly one-seventh of American cities have suffered from water shortages during the past two years. Many of the southwestern regions, where the demand for water nearly equals or already exceeds the readily available fresh-water supply, continue to grow in population. Therefore, for determination of new water sources, extensive engineering studies are being conducted. Besides many appreciable research programs (University of California, Rutgers, etc.) some states and federal bureaus have appropriated millions of dollars for a comprehensive study of salt-water barriers in ocean bays or for distilling of sea water, as a means of creating a new source of water. It is imperative to investigate all possibilities for covering the water shortage in this country. But it seems a squandering of means to provide artificial biological purification of sewage, then to rush the effluent down to rivers and ocean, and then try to reclaim the water from the ocean.

Conclusions

Actual experience for half a century in Europe with skillfully designed and properly managed sewage farming has demonstrated that sanitary sewages and many industrial wastes can be successfully used for agricultural, industrial, and other purposes. Studies and practice in more than 100 localities in southern states of this country have shown that water recovered from most sewages through land disposal can be employed as a reclaimed water supply source in water-shortage areas. The sewage is usually prepared for irrigation by being given primary treatment. After that the processes of natural soil filtration and biochemical stabilization can produce an oxidized and well-treated percolation water. But reclamation programs planned only for ground-water replenishment are usually unsound economic ventures (9). Therefore, the emphasis should be placed on conservation of the agricultural values in sewage, greatly reducing the immense fertilizer bill and improving soil condition.

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Industrial Wastes

FLOATABILITY OF OIL AND GREASE IN WASTE WATERS*

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PART I. ANALYTICAL STANDARD

Need for Measurement of Floatable Oil

Most of the objectionable conditions that arise from the presence of oil or grease † in waste waters discharged to sewers or directly to ultimate disposal sites are due to the oil or grease which floats to the surface. That which remains colloidally dispersed is of different significance. In a primary sewage treatment plant it is not objectionable, nor will it cause any complaint when discharged to the ocean or to a harbor. In a plant employing biological oxidation, the colloidal oil and grease may be in large measure removed in the biological sludge, and it may affect the oxygen demand if it is easily oxidized. In the sludge digestion tanks its effect depends largely on whether it is digestible (oxygen-containing compounds) or non-digestible (hydrocarbons).

Since oil which floats to the surface is of different import from that which does not, it is evident that it will be desirable, if possible, to make a corresponding distinction in quality criteria which waste waters are required to meet. An investigation was undertaken to determine a suitable way to make this distinction.

Inherently Arbitrary Character of a Test

It is at once evident that any test for separability or floatability of oil must involve arbitrary factors. There is no definite dividing line between colloidal and non-colloidal oil or grease. Just as in the "settleable solids" test using Imhoff cones, a "floatable oil and grease" test must specify an arbitrary time and an arbitrary size of vessel.

It also became evident that there is not a simple test which invariably will give significant results when applied to any kind of waste water. In this respect also a "floatable oil" test is similar to a "settleable solids" test. By way of illustration, two men each picked up at the same time a sample of refinery waste water in floatable oil tubes, carried them to the laboratory, and allowed them to stand. It was found that one tube had a large amount of flocculent material floating to the surface, while in the other tube this flocculent material was at the bottom. A small difference in the amount of disturbance during carrying had

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† It is unfortunate that present sanitary engineering terminology does not supply a simpler term for the class of materials covered by the expression "oil and grease," or "oils and fats," or "ether soluble material." It has been suggested that the Latin word "unctus" be adopted for this purpose, since it means exactly what is being talked about. The author favors this, but has not used it generally in this paper.

caused this difference of behavior. Where there is gassy suspended matter of this sort which may easily be either floatable or settleable, neither the floatable nor settleable test will mean much. The occasional finding of samples of this sort does not materially reduce the general utility of either test.

Choice of Test Method

The procedure finally adopted for securing practical results establishes a category of oil and grease which under specified conditions separates by any or all of the following processes:

1. Floats to the surface.
2. Clings to the wall of the glass vessel used for the test.
3. Is carried to the surface with solid matter.
4. Is present in colloidal form in the water which saturates a surface layer of floating solids.

If the sample is such that the oil found in the test comes almost entirely from sources 3 or 4, the test does not have its usual significance, yet even so a quality limitation based upon this test is not likely to lead to unreasonable conclusions. Normally the test will not be applied to waters of this sort. Oil or grease which clings to the walls (item 2) generally would have floated if it had not been caught on the walls.

The category of oil and grease separated in the standard test here specified is reasonably definite. This category is called "floatable oil and grease" (or floatable unctus), but with recognition of the fact that the name is only approximate.

The amount of material floating or settling from a sample in a specified period of time is dependent upon the depth of the vessel. On the basis of availability of equipment, convenience of size, and the desirability of using a volume of one liter, a tube has been specified which is 70 to 72 mm. in diameter. The liquid depth when the tube is filled to 1 l. should be about 25 cm. It is believed that a 1-hr. settling time gives results of greatest significance as a standard test, but other periods of settling may give significant information on separation rates. With a 1-hr. standing time, the "capacity factor" (defined later in this paper) is 50 min. per foot, or 160 min. per meter. The test may be expected to give results similar to a tank 5 ft. deep with a detention time of 6 hr.

Attempts were first made to remove floated oil from the surface of a test vessel by removing a thin surface layer, or by flooding with benzene and then removing this by suction. It is difficult to get the benzene into effective contact with some of the oil or with grease which has collected at the meniscus. This procedure also misses the oil clinging to the walls of the vessel. The simplest procedure seems to be the best, which is to draw off the water from the bottom, leaving the separated oil to be collected by addition of a solvent. Chloroform is chosen because of its high solvent power and low boiling point.

The procedure accepted as standard by the Los Angeles County Sanitation Districts is as follows:

Determination of Floatable Oil and Grease

Materials

Floatable oil tube. This shall be a glass tube of inside diameter between 70 and 72 mm., tapered at the bottom to a glass stop-cock and tapered at the top to an opening fitted with a glass stopper. This opening should preferably be 20 mm. or more in diameter (*e.g.*, 24/40) to facilitate cleaning. The tube shall be circled with a mark to indicate a volume of one liter, and this 1-l. mark shall be on the straight portion of the tube, below the shoulder. Before each use of the tube, it shall be scrupulously cleaned, by brushing with a mild scouring powder or by soaking with chromic acid cleaning solution or

other suitable cleaner, so that water will form a smooth film on the inside of the glass. The stopcock shall be lubricated only with water.

Chloroform. This shall be laboratory grade chloroform. Suitable steps must be taken to assure that it contains no dissolved non-volatile matter, as by testing a sample for residue on evaporation, or by distilling before use. The fact that a sample obtained from one source of supply shows no residue must not be construed as evidence that continued deliveries from the same source will necessarily always be free from residue. Chloroform reclaimed from previous analyses must be re-distilled before re-use because small accumulations of slightly volatile oils may introduce significant errors into subsequent analyses.

Sampling

Samples for floatable oil or grease must be taken at points of high turbulence, or where the water has a free fall in such a way that a representative portion can be obtained. Samples dipped from a quietly flowing stream are generally worthless for floatable oil or grease tests. The sample may be taken directly in the floatable oil tube, or a dipper may be used if the sample is poured immediately into the tube. With most wastes, especially oil field waste waters, and refinery effluents, it is impossible to get reliable results by sampling in a bottle and taking this to the laboratory for subsequent transfer to the floatable oil tube. Exceptions may be made in the case of wastes containing much greasy sludge or scum which, by shaking of the bottle, can be re-dispersed to its original condition, but in no case should such samples be kept more than 2 hr. before beginning the test.

Procedure

Fill the floatable oil tube to the mark. Support it in a strictly vertical position, preferably in a location which will minimize temperature change and resulting convection currents. If the temperature of the waste water is considerably higher than atmospheric temperature, it may be necessary to immerse the tube in a body of the waste water or in other suitable water bath.

After 1 hr. draw off the water, stopping before any surface oil or other floated material is removed. Sludge which has settled to the bottom during the settling period or which has clung to the sides should be drawn off as completely as possible, and to this end it is often desirable to give the tube a slight back-and-forth rotation about the vertical axis to dislodge such sludge so that it will go out with the water. If there is much scum on the top, some of this may mix somewhat with the underlying water as it moves down the tube. In this case it is necessary to stop drawing off before any of the float has been lost, and it is well then to wait a few minutes until a sharper boundary permits the withdrawal of more water. It is important to remove the water as completely as possible without losing floating material. If more free water separates upon longer standing after removal of the bulk of the water, this should also be drawn off, as the minimizing of residual water facilitates subsequent operations.

Add to the tube 50 to 100 ml. of chloroform and shake vigorously. Allow to settle and draw off the solvent into a dry beaker or flask. Then pour this solvent through a dry filter paper into a clean, dry 300-ml. Erlenmeyer flask, taking care not to let any drops of water get onto the filter paper. Add a second portion of chloroform to the floatable oil tube and repeat these operations, pouring the solvent through the same filter paper. If there is much sludge in the tube, a third and perhaps fourth extraction may be necessary, or larger portions of solvent may be required. (In this case it may be necessary to distill off part of the filtered solvent solution before adding successive portions to the flask.) Wash the filter paper carefully with fresh chloroform. Evaporation causes oil to creep up the paper, and it is therefore desirable to use a dropper or a solvent wash bottle with a fine tip to facilitate complete washing.

Place the flask in a vessel of hot water and connect to a condenser to recover the solvent, using glass connections. Distill down to a volume of about 1 ml. Remove the flask from the water bath and pour out the vapor by tipping until the solvent is substantially all gone. Wipe the outside clean. If the quantity of oil or grease is small, hang the flask neck downward in a ring near the balance; weigh after 1 to 2 hr. If the quantity of oil is so large that

it may run out of the flask, lay the flask on its side and weigh the next day, or after reasonable assurance that no significant amount of chloroform remains.

To obtain the tare weight of the flask, wash it out with several portions of chloroform, hang neck downward near the balance for 2 hr., and weigh.

Report the weight of oil or grease found as "floatable oil and grease" (or floatable unctus) in milligrams per liter.

The standard settling time is 1 hr., but other settling times may be used provided this is stated in reporting the results.

Demonstration of Method

A test of this sort is, of course, not expected to show high precision. Practical utility of the test is not materially impaired on this account. An indication of reproducibility is afforded by a series of triplicate tests, as shown in Table I.

The laboratory of the Wilshire Oil Co. refinery made a series of 15 duplicate tests on their separator effluent. Remarkably close agreement was found, as shown in Table II.

TABLE I.—Comparison of Triplicate Tests

Sample	Floatable Oil (mg./l.)			
	A	B	C	Av.
Meat packing waste water	53	67	52	57
Meat packing waste water, after separator	22	29	25	25
Sewage	52	44	48	48

TABLE II.—Floatable Oil in Refinery Effluent

Sample Number	Floatable Oil (mg./l.)		
	First Test	Second Test	Difference
1	10.8	10.6	0.2
2	2.2	2.4	0.2
3	10.1	9.0	1.1
4	7.7	7.5	0.2
5	10.6	10.2	0.4
6	11.2	10.9	0.3
7	7.6	7.1	0.5
8	8.9	8.2	0.7
9	9.9	9.6	0.3
10	5.7	6.0	0.3
11	6.5	6.4	0.1
12	6.8	7.4	0.6
13	5.1	5.2	0.1
14	5.5	5.7	0.2
15	6.4	6.0	0.4
Av.	7.6		0.37

In view of the different import of floatable and total oil, and the satisfactory performance of this test, the Los Angeles County Sanitation Districts have now made this test the basis of a quality criterion for acceptability of a waste for discharge into the sewer as pointed out by Anderson (2).

PART II. FLOATABILITY, OR SUSCEPTIBILITY TO SEPARATION, AND SEPARATOR DESIGN

Need for Measuring Rates of Separation

It has been pointed out by Weston (1) that percentage removal of oil by a separator is a poor criterion of performance, for some wastes may carry much floating oil along with water that is otherwise reasonably clear, whereas in other cases there may be a large amount of emulsified oil that will separate only very slowly from the water.

Adequate understanding of a disposal problem for wastes containing oil and grease often requires a study of the rates of gravity separation. Such rates are determined by subjecting samples of the water to settling for various periods of time, until enough data are secured to draw a curve of oil or grease content *versus* time.

General Techniques for Floatability Curves

For preparing a curve of this sort it is necessary to settle separate portions of the waste water for each desired time interval. Thus, from four to six

identical samples are poured into glass cylinders or into floatable oil tubes. At predetermined times the water is withdrawn from one after another, leaving behind the floated oil and grease. Analyses may be made either on the water withdrawn or on the separated oil and grease, or both. If a small amount of oil is separating from a waste with much emulsified oil, determination of the portion which floats is most practical, but if much oil is separating, leaving but little in the water, then analyses of the water will give the more reliable results.

The removal of oil and grease from water frequently occurs, at least in part, by downward settlement of solid matter, especially in wastes from the processing of meat and other foodstuffs. If much oil and grease is carried downward, then significant results require that tests be made on the intermediate water between the settled sludge and the floated matter. An ordinary graduated cylinder with a siphon has proved useful for this purpose.

The water layer, after the interval of settling, has a graduated oil and grease content from bottom to top. It is not possible to know what level represents the average oil and grease content. Therefore, it is ideally desirable when the analyses are to be made on the water, to draw off all of the water between the sludge and scum layer, but it has been found most practical to leave about 10 per cent of the water in the bottom when using a siphon in a graduated cylinder. There is a resulting theoretical error which, however, is inconsequential. In samples which show negligible settling of sludge, the floatable oil tubes, draining from the bottom, have been found most convenient.

Theoretical Relationship between Laboratory and Field Results

Theoretical studies of gravity separation, either downward or upward, point out that area divided by flow (or flow divided by area) should be the design factor, rather than detention time. Stated otherwise, for the same flow and same surface area, the depth of a settling tank is not important, as long as horizontal flow velocity does not cause turbulence. The most important qualifying factor to modify this elementary theory is the fact that flocculation of suspended matter alters settling rates. This is particularly noticeable in primary sewage sedimentation tanks, where fine material which at first has very little tendency to settle will, after an hour or so, flocculate and settle. The same phenomenon is noticeable to some extent with some floating material. If a laboratory cylinder serves as a model for a much deeper prototype sedimentation tank, and if the comparison is made, according to the simple theory, on the basis of time divided by depth, the deeper prototype would have the chance of superior efficiency because of the effect of flocculation. This effect is counteracted to a variable extent by the imperfections of any practical sedimentation tank. Turbulence and short-circuiting reduce the possible efficiency of the tank.

All things considered, it appears that the best basis for relating laboratory tests to separator design or performance is the time-depth ratio.

There are many ways that this can be expressed. "Gallons per square foot per day" is a common expression for loading. This might also be called square feet per c.f.s., or simply feet per second, which may be thought of as a rate of rise. What is needed, however, for the practical application of settling curves is not a loading factor but the reciprocal, which is a capacity factor. An attempt to draw a settling curve on the basis of loading would require that the raw sample be plotted at infinity which is not practical. Time divided by vertical distance should be used; minutes per

foot is convenient (or seconds per centimeter). This is the same as detention time divided by depth of the vessel, and thus is easily related to commonly available data.

Examples of Applications

Figures 1, 2, and 3 show results of separation tests on wastes from a barrel washing plant, a meat packing plant, and a petroleum refinery.

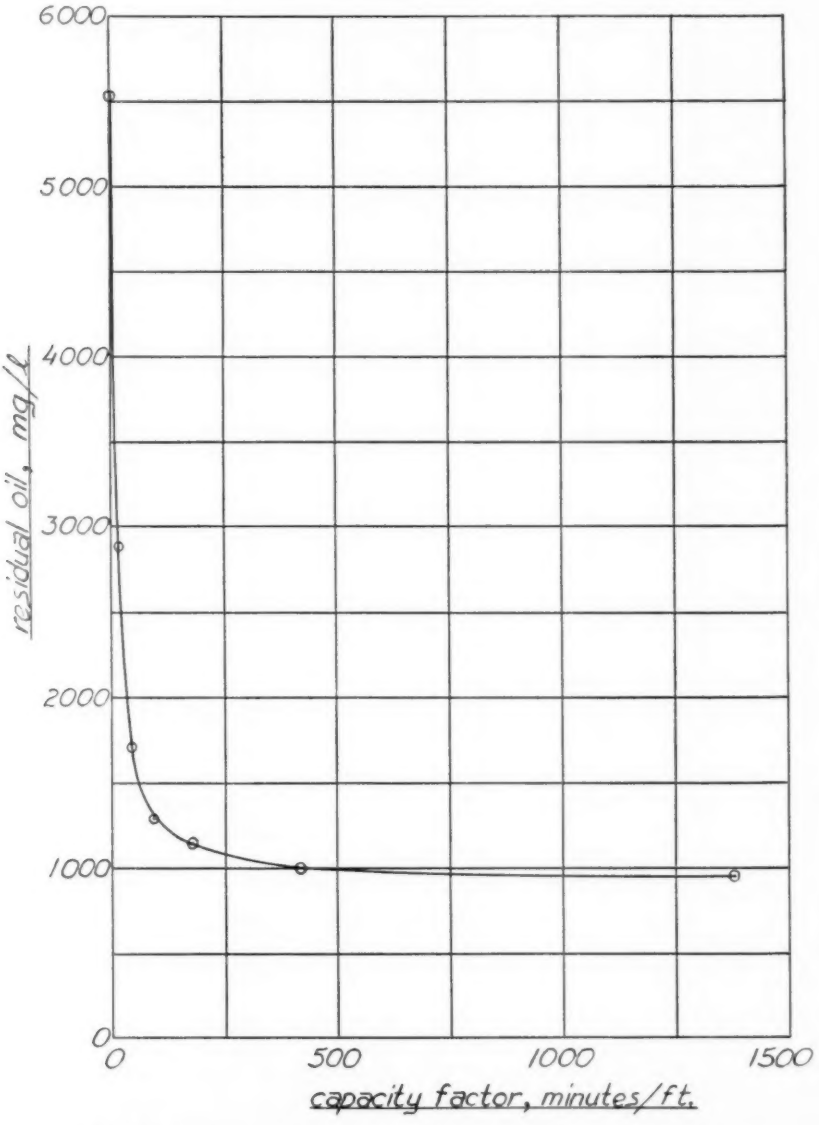

FIGURE 1.—Oil removal from waste water from a barrel washing plant.

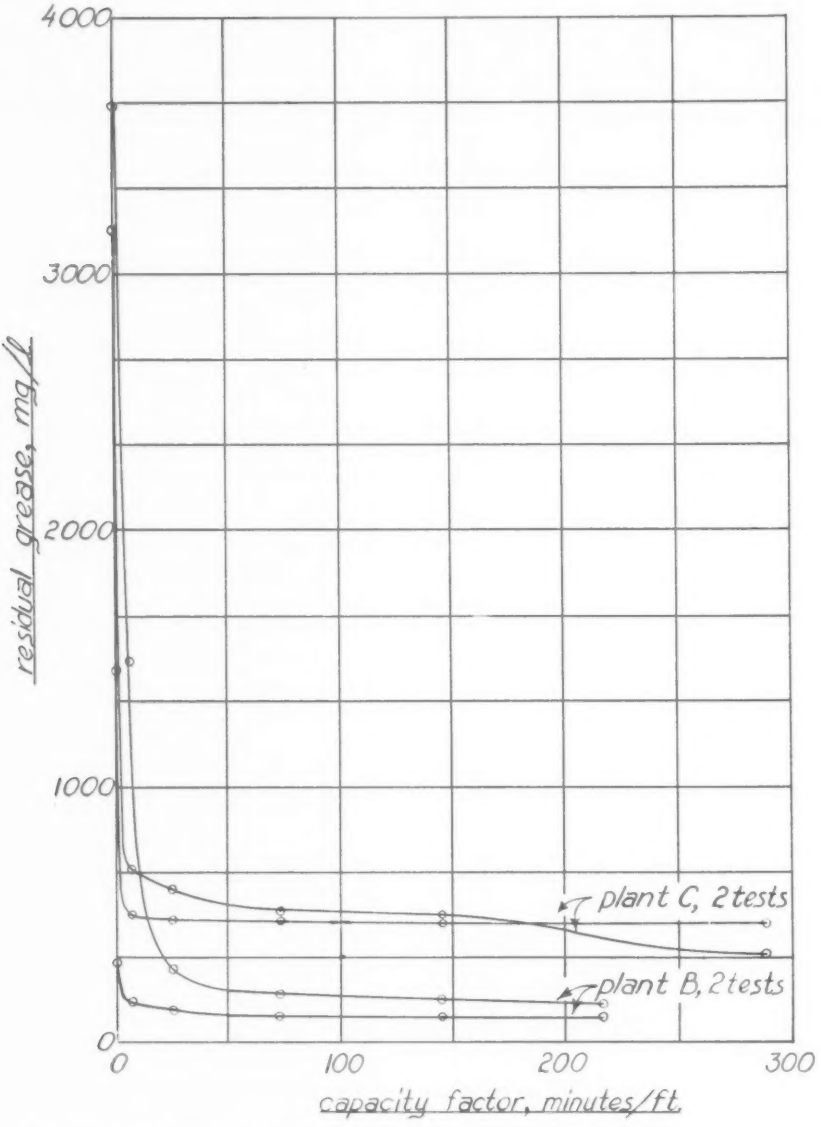

FIGURE 2.—Grease removal from waste water from two typical meat packing plants.

Figure 2 shows a rapid separation of grease from the waste water of plant C, down to a level where further separation is very slow. On the basis of these samples, a capacity factor of 5 to 10 min. per foot may be expected to produce a water having very little floatable grease, although the content of highly dispersed grease remains high. The effluent after a short period of settling should be satisfactory for discharge into sewers lead-

ing to a primary sewage treatment plant. Little could be gained by increasing the size of the grease separator. If removal of the dispersed oil is necessary, it must be accomplished by flotation or sedimentation aided by flocculating chemicals, or in some other way.

The waste water from plant B yields its grease content more slowly, although a lower final grease content is reached. Sample 2 from this plant

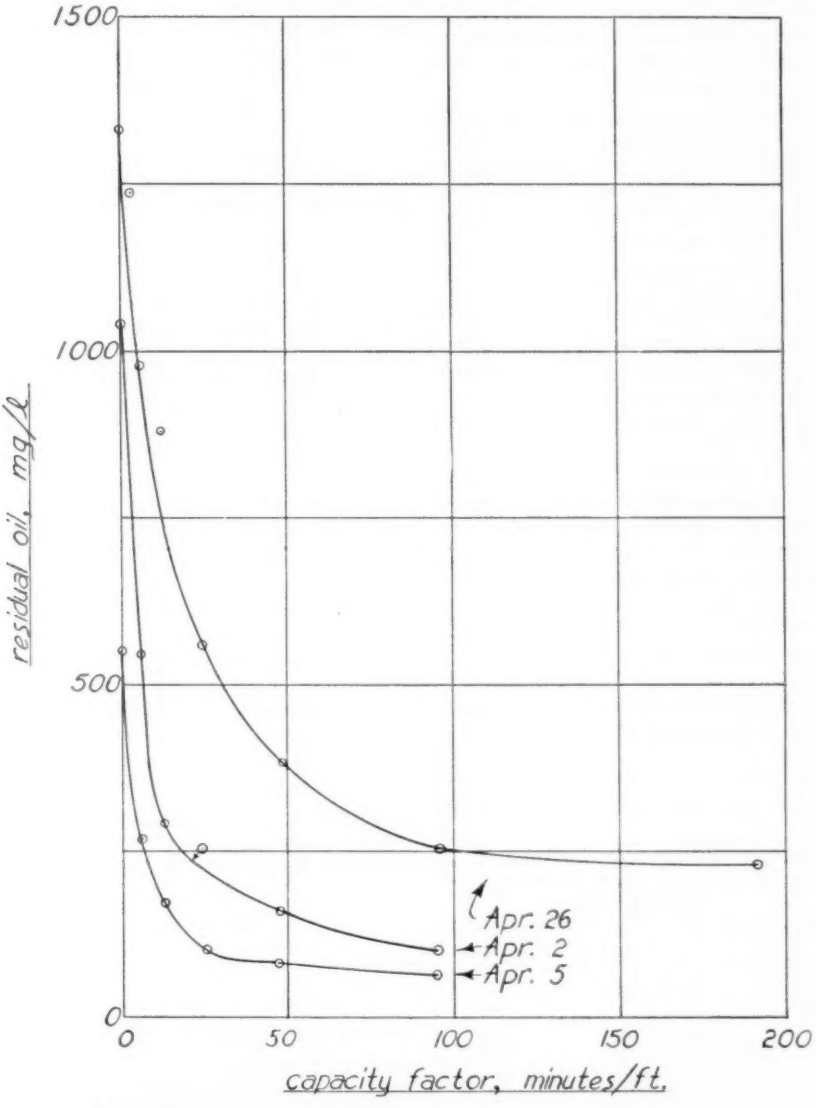

FIGURE 3.—Oil removal from waste water from a typical oil refinery.

would continue to yield grease for a relatively long time, and such water must have a longer detention time, otherwise the effluent will fail to meet floatable oil criteria. Twenty minutes per foot would appear to be needed.

The foregoing paragraphs are not intended to imply that two tests from a plant would serve as a basis of design, but examination of a sufficient number of samples properly selected will serve this purpose.

Eight tests upon the waste water from a large refinery served design purposes in that case. Three typical curves of the eight are shown in Figure 3. In four of these cases observations were made of flow rates and predictions were made of the effluent composition from the existing refinery separator (Table III). Possible sources of variation would be expected to lead to greater differences between laboratory and plant results than appear in Table III; hence the close agreement must be partly fortuitous. But in any case it is evident that the laboratory tests on this refinery waste were closely related to separator performance.

Concern has been expressed lest a colloidal suspension may "break" upon dilution with sewage or with the receiving water. This may occur with concentrated emulsions or, perhaps, with emulsions stabilized with soap. As far as application of control standards is concerned, the problem is simply handled by ascertaining whether a reduction of colloidal stability occurs upon dilution with the receiving stream. By way of illustration, a sample of refinery waste water destined for disposal into a harbor was settled for various periods of time, with determinations of the percentage of oil floating. Similar series were run with mixtures of sea water and refinery waste, containing 33 per cent and 67 per cent of sea water (Table IV).

TABLE III.—Comparison of Predicted and Observed Oil Contents of Refinery Separator Effluent

Sample No.	Oil Content of Effluent (mg./l.)	
	Predicted	Observed
1	64	60
2	110	112
3	178	183
4	110	110

TABLE IV.—Effect of Sea Water Admixtures on Rate of Separation of Oil from Refinery Waste Water; Original Oil Content = 382 P.P.M.

Capacity Factor* (min./ft.)*	Oil Remaining (%)		
	Undiluted Waste	33% Sea Water	67% Sea Water
18	—	—	79
24	—	62	76
36	50	—	71
48	44	54	—
192	39	—	—
1,540	31	30	42

* Capacity factor = detention time, in minutes, divided by depth of tank.

For certain reasons the time intervals are not the same for all samples, but it is evident that the stability of the colloidal oil was increased rather than decreased. Another mixture of sea water with refinery waste water gave similar results, and so did mixtures of sewage with barrel washing waste and with refinery waste water. One should not, of course, generalize on the basis of these four cases, and in any doubtful case tests should be made to ascertain the effect of the waste water after it is mixed with its potential subsequent diluents.

Summary

Part I

A test has been specified which measures the amount of oil and grease separating under standard conditions from a waste water sample by floating to the surface or by being carried to

the surface or by clinging to the walls of the vessel. The test is called a "floatable-oil and grease" test, since it approximately represents the amount of oil and grease which may be skimmed from a settling tank at analogous loading. Because of the different import of the oil and grease which floats as compared to that which does not, this test affords a criterion useful in judging the acceptability of a waste for discharge in various situations.

Part II

By using variable detention times in measuring the amount of oil or grease separating from a waste water, curves are drawn showing the relationship of these variables. These curves can be used as a basis of design or for prediction of performance of separators, provided comparisons are made on the basis of a capacity factor expressed as "minutes per foot," or some comparable measure, the "minutes per foot" factor being equal to detention time in minutes divided by depth of the tank.

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CONSTRUCTION PROBLEM VIEWPOINTS AIRED

According to *Plans and Specs*,* official organ of the Municipal Contractors Association, a recent survey of that group's members brought 100 per cent results favoring centering of complete responsibility for procuring materials and equipment for construction jobs upon the contractor. In their replies, members stated the necessity for centering complete responsibility and authority in the hands of the contractor if he is to be able to plan the progress of his job and be assured that all equipment will be available when required. The practice further assures against improper ordering and the issuance of incomplete orders. Also, the contractor is able to handle delivery promises more readily when they are made directly to him. In statements relating past experience, it was shown that costly delays can result when responsibility for placing orders is in the hands of a third party.

As one contractor summed it up: "The contractor is responsible for building a complete plant and placing it in operation. He should therefore have complete responsibility for procuring all materials and equipment so that he can expedite deliveries, handle claims on shortages and breakage, and schedule factory service men, and so that he will know exactly what is being supplied."

Response to the survey further showed that the contractors agree that in order to secure for owners the most satisfactory results, it is of first importance that the engineer require through clearly worded specifications the exact equipment (or equal) that is desired to best fill specific needs. This practice would insure selection of equipment, on a basis of specifications rather than names, that will meet the required standards.

The survey was conducted as a follow-up on a resolution presented in January, 1953, by a joint committee of the Associated General Contractors of America, Inc., and the American Public Works Association. The resolution urged that governing bodies should permit contractors to furnish and install all machinery, equipment, and materials to be incorporated in a construction job, except when special circumstances would make it clearly contrary to the best interest of the agency involved.

* Vol. 1, No. 11, p. 4 (Sept., 1953).

SOLUBLE OIL WASTES TREATMENT BY PRESSURE FLOTATION *

By Austin H. Beebe

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It is the purpose of this paper to discuss an industrial waste treatment plant of the pressure-flotation type, which was installed to treat process waste at the Trenton, Mich., plant of the Chrysler Corporation. The treatment plant, which has been in operation since May 5, 1952, is reported to be the first of its type to be used in the automotive industry.

The principal equipment for the reduction of pollution in the waste consists of a Colloidair separator, rated at 400 g.p.m. An 830-sq. ft. plate and frame filter follows the separator in order to provide additional control of effluent quality. Housed in a building 54 ft. by 50 ft. by 20 ft., the equipment provides for treatment of the process wastes from a 1,000,000-sq. ft. plant.

The manufacturing plant design includes three separate sewer systems: storm water, sanitary, and process wastes. The raw process waste consists principally of spent soluble oil coolants, washing machine waters, and some free oil. The effluent leaving the treatment plant is discharged to the Trenton sewer system and must meet the exceptionally high standard specified for industrial waste entering that system.

In designing the treatment facilities (Figure 1) it was estimated from the operations contemplated that the manufacturing plant would eventually reach a peak discharge of approximately 250,000 gal. of oily waste in a 24-hr. day. To process this volume it would be necessary to operate the treatment plant for two shifts, with about 6½ hr. of actual operating time per shift, and at a rate of about 320 g.p.m. These estimates indicated that waste processing equipment having a rated capacity of 400 g.p.m. should provide adequate facilities.

Selection of Equipment

Considerations which lead to the decision to install pressure-flotation type equipment were as follows:

1. The desired capacity was readily available. The Colloidair separator, which was the unit under consideration, provides continuous processing when desired, and requires relatively little floor space.
2. Visits were made to several Southern California installations in which such separators are used to treat oily industrial wastes similar to those Chrysler proposed to process.
3. A pilot plant operation was conducted at the corporation's Plymouth Division using a 50-g.p.m. separator furnished by the manufacturer. The results observed indicated that the equipment should do the job in a satisfactory manner.

The other principal piece of equipment selected was an 830-sq. ft. plate and frame filter. This was necessary in order to meet the Trenton sewage treatment specifications for oil content of the effluent, which are not more than 10 p.p.m. average or 30 p.p.m. maximum for one shift.

* Presented at 1953 Annual Meeting, Michigan Sewage and Industrial Wastes Assn.; East Lansing, Mich.; Sept. 21–23, 1953.

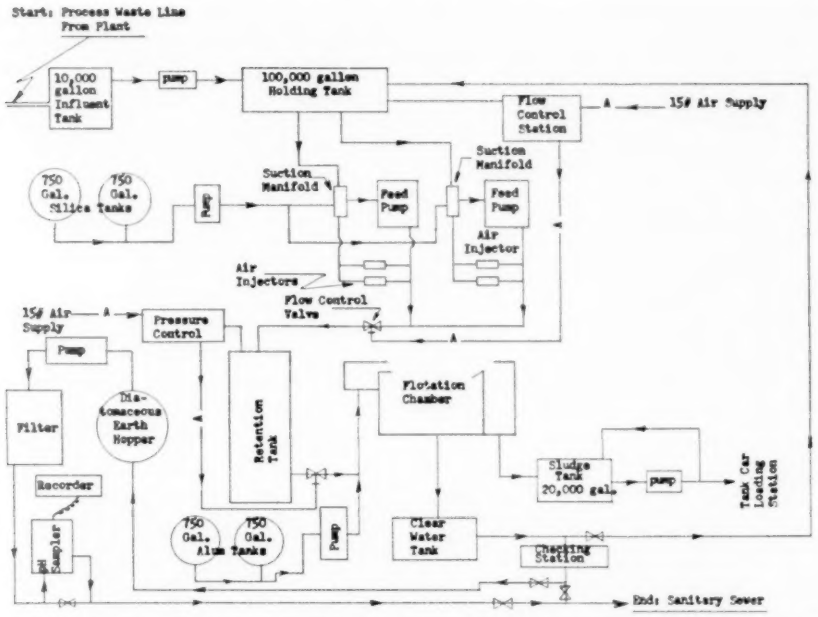

FIGURE 1.—Flow diagram for soluble oil waste treatment at Trenton, Mich., plant of Chrysler Corporation.

Accessory equipment on the operating floor includes five chemical mixing tanks, duplicate waste transfer pumps, automatic filter aid feeder with pump, and sludge transfer pump. Accessory facilities below the operating floor level include duplicate feed pumps and air injector systems.

Waste Storage Tanks

Below the operating floor there are three storage tanks—one 10,000-gal. settling tank to receive the raw waste and permit the heavier suspended solids to settle out; one 20,000-gal. sludge tank equipped with a pump for transferring separated water to the holding tank, or transferring sludge to a disposal system; and one 100,000-gal. holding or storage tank.

In deciding on the capacity of the holding tank, it was considered that a large storage facility has several advantages. The concentration of contaminating materials can be leveled out, reducing the need for frequent adjustment of chemical feeds. In addition, a more uniform rate of flow through the separator can be maintained and effects of temperature changes in the waste flow can be minimized.

Operating Principle of Separator

Suspended particles with densities less than or approaching that of the liquid tend to separate by floating. Flocculent suspensions heavier than water may be much more rapidly separated by flotation with attached air than by settling procedures. The operating principle of the Colloidair separator is flotation by means of minute air bubbles attached to particles suspended in the liquid. In using dissolved air flotation, it is obvious that the capacity of the treatment unit can be based on the rate of flotation rather than on settling times. This results in relatively small space requirements and short retention times.

Operating Procedure and Treatment

The oily waste is transferred from the factory by gravity through a 15-in. line into the 10,000-gal. sump located under the waste plant operating floor, where some of the heavier solids settle out. From here the waste is pumped to the 100,000-gal. holding tank, also under the operating floor. Each day before starting the separator, floating oil is removed from the holding tank by a manually operated skimmer located at one end. The oil flows by gravity to the sludge tank. As the process wastes containing emulsified oil, suspended solids, and the free oil not removed by skimming pass from the holding tank through a centrifugal feed pump, about 1 per cent by volume of atmospheric air is injected on the suction side, and is dispersed in the waste by the pump's impeller. The waste next enters a pressure-retention tank (Figure 2) located at one end of the separator where the air is dissolved in the liquid at a pressure of about 35 p.s.i. The holding time in this tank is about 1 min.

Automatic control of waste flow through the pressure tank is brought about by a liquid level controller in the holding tank. This in turn operates a flow control valve to the flotation chamber so that the flow treated

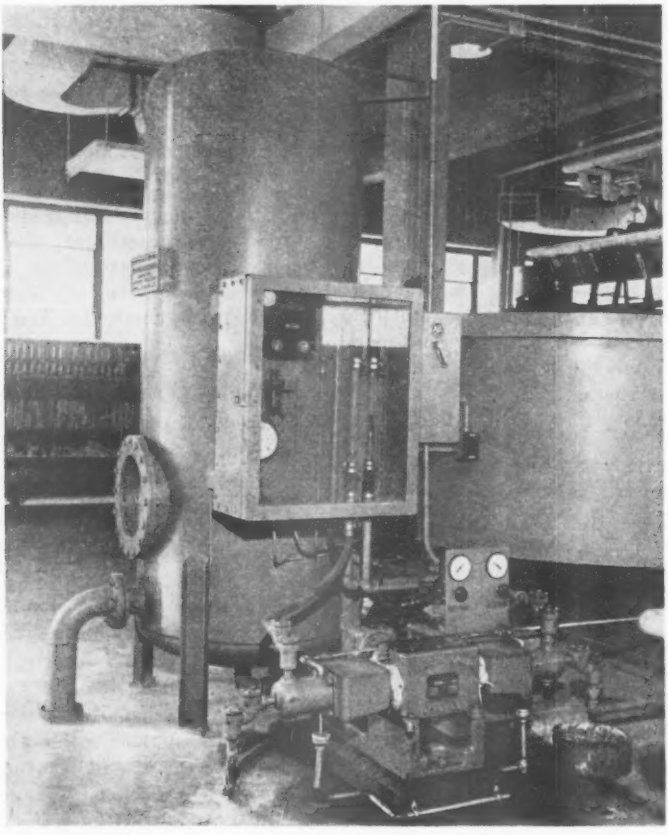

FIGURE 2.—Pressure-retention tank and chemical feed equipment.

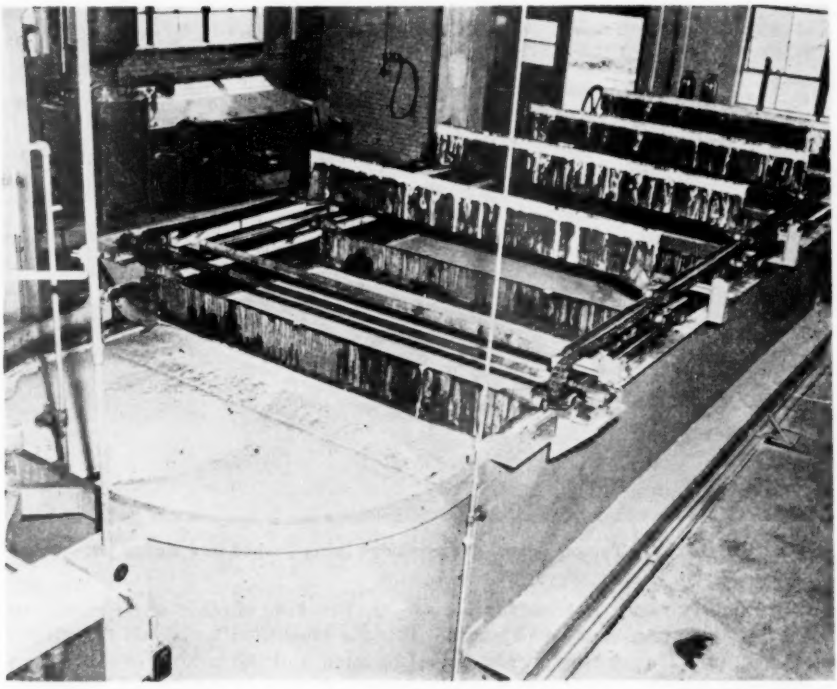

FIGURE 3.—Colloidair separator in operation, showing fine cloud of air bubbles and flights skimming grease layer.

will vary with the effluent. The same air signal which operates the flow control valve also actuates chemical feed valves so that correct feed is maintained proportional to flow.

Oil emulsions are broken by chemical treatment with small amounts of aluminum sulfate and activated silica. In the Trenton installation the silica dispersion is injected along with the air on the suction side of the pump. The aluminum sulfate solution is injected between the pressure retention tank and the flotation tank.

Flotation

From the pressure tank the waste flow is released through an automatic valve to one end of the open flotation chamber, where the dissolved air comes out of the solution as a continuous cloud of extremely minute air bubbles. These attach themselves to the released oil droplets and other suspended material, floating them as a surface layer on the water (Figure 3). This layer is skimmed by continuous flight scrapers, moved up an inclined ramp and into a sludge pit at the opposite end of the flotation chamber (Figure 4). Holding time in this chamber is about 18 min. After the chemically treated waste enters the inlet section of the flotation tank all separation steps are visible, including flotation and skimming of grease, removal of grease and sludge, and separation of the clarified water.

The flotation of the suspended material is accomplished without turbulence or frothing because the release of the dissolved air occurs uniformly over the entire area of the inlet section. Clarified water freed from grease

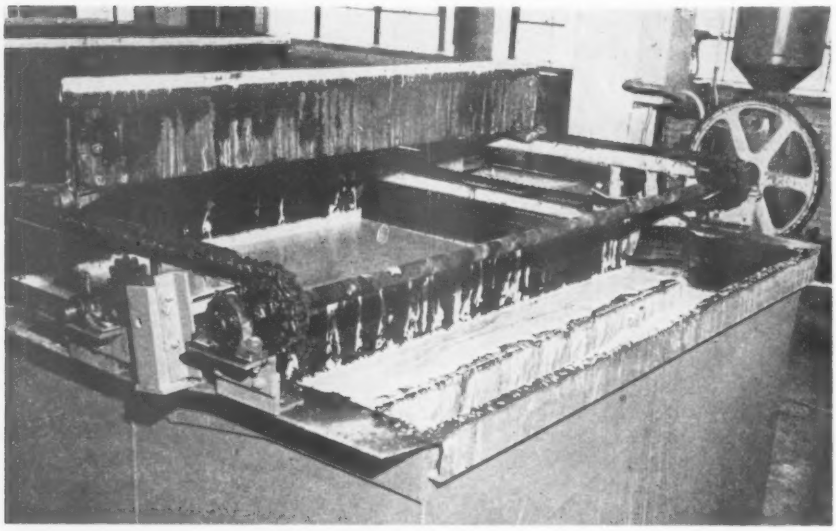

FIGURE 4.—Typical floated grease sludge being pushed into sludge pit.

is continuously removed from the bottom of the flotation chamber by three tubes running transversely across the bottom and ending in adjustable riser tubes in the clarified water compartment, which is attached to one side of the flotation tank. The water is discharged from each tube as a cascade spray. Adjustment of the riser tubes determines the operating level in the flotation chamber. By this device the level may be adjusted so that the flight scrapers remove the floating layer of solids and grease to any depth desired. This makes possible selective removal of sludge from the very top layer if a concentration of sludge is desired.

Filtration

As a secondary treatment, the clarified water is passed through a diatomaceous earth, 830-sq. ft., plate and frame filter (Figure 5), the effluent from which goes to the Trenton sewer system.

In summary, then, Collaidair separation of oily wastes is made up of the following steps:

1. Breaking of oil-in-water emulsions by the combined action of the aluminum ion and the acidity of the aluminum sulfate solution.
2. Flocculation of aluminum hydroxide by the alkalinity of the sodium silicate solution.
3. Flocculation of activated silica and growth of the silica micelles. The floc consists of a mixture of aluminum hydroxide and colloidal silica.
4. Adsorption of grease by the floc. Flotation of grease and suspended solids by colloidal air.
5. Separation of grease and water by flight skimming and bottom withdrawal of clarified water.
6. Filtration to remove any remaining floc and adsorbed grease.

Space Requirements of Pressure-Flotation Equipment

The 400-g.p.m. treatment unit at Trenton is 27ft. 4 in. long, 7 ft. 6 in. wide, and 5 ft. 7 in. deep. An additional 4 ft. of length is required for the pressure retention tank. The clarified water tank, which is attached to one side of the flotation chamber is 16

ft. long, 3 ft. 5 in. wide and 5 ft. 7 in. deep. At the discharge end this tank has a 90° V-notch weir for convenient checking of the approximate flow of the separated water. At the surface of the separator there are nine wooden flight scrapers with neoprene edges moving on an endless chain driven by a ½-h.p. motor.

Sludge Handling

The skimmed sludge from the separator, consisting of oil and aluminum hydroxide-silica floc, flows by gravity to the 20,000-gal. sludge tank. This tank also receives the free oil skimmed manually from the holding tank. After gravity separation has occurred, the water is pumped to the holding tank for recycling, and the concentrated sludge is pumped through a pipe and fire hose in the rear of the plant to containers.

Cleaning of Sumps, Holding Tank, and Filter

The 10,000-gal. sump receiving waste from the manufacturing plant was cleaned at the end of one year's operation. The 100,000-gal. holding tank was cleaned on the same day as the smaller one. It contained about a foot of rather thick sludge, some of which could be pumped. The time required to clean both tanks was 18 man-hours. The 20,000-gal. sludge tank is cleaned weekly.

It appears necessary to clean the plate and frame filter after about every 50 hr. of operation.

Operating Troubles

At the Trenton plant the separator is currently in operation about 5½ hr. a day for 5 days a week. This intermittent operation has given rise, at times, to filtration trouble, in which portions of the diatomaceous earth precoat may dry and become detached from the filter cloth, resulting in incomplete removal of the floc. This has been overcome to a considerable extent by applying a fresh precoat to the filter pads each morning.

Some trouble was experienced in the early days of operation with loss of

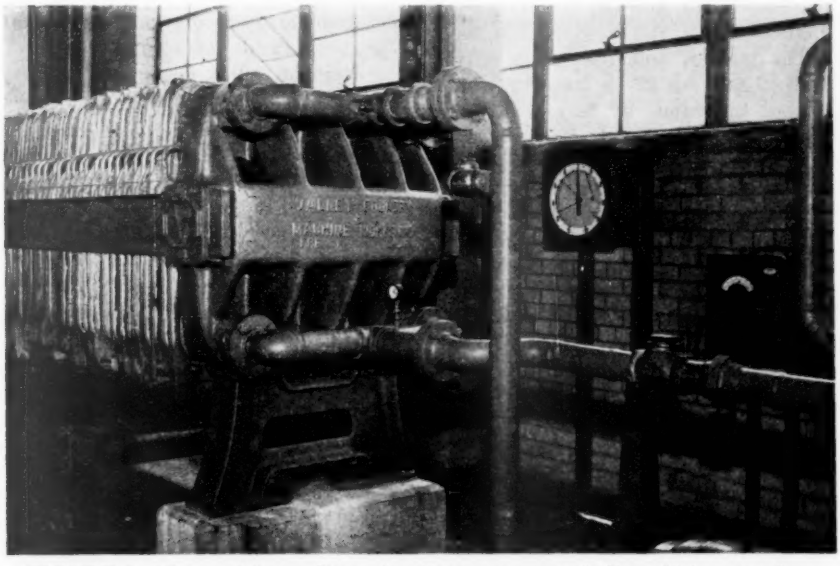

FIGURE 5.—Plate and frame filter using diatomaceous earth filter aid for secondary treatment of oil-bearing wastes.

TABLE I.—Summary of Analytical Results for Colloidair Operation

Determination	Raw Waste[1]		Separator Effl.[2]		Filtered Effl.[1]		Trenton Municipal System Requirements	
	Range	Median	Range	Median	Range	Median	Gen. Av.	1-Shift Max.
Grease (p.p.m.)	50–16,450	717	6–89	27	0.8–25	8.2	10	30
pH	5.9–10.8	8.1	4.1–7.2	5.2	4.1–8.8	6.7	6.5–9.0	10.0
Susp. solids (p.p.m.)	48–38,400	1,941	7–77	35	0–70	9	200	400
Cyanide (p.p.m.)	0	0	0	0	0	0	1	1
Chlor. demand (p.p.m.)	2.5–90	20	0.8–5.8	1.5	0.6–11.8	2.1	10	15
Total solids (p.p.m.)	—	—	—	—	282–596	396	Not spec.	Not spec.

[1] Samples taken weekly from May, 1952, to June, 1953.
[2] Samples taken during May, June, and July, 1952.

chemical feed. In every case the lines or valves were plugged by undissolved chemicals. Air agitation of the aluminum sulfate solution and the use of an improved quality of sodium aluminate has eliminated the trouble.

Analytical Results

Regular analysis of samples from the Trenton plant Colloidair separator provides the information required for several purposes—specifically, chemical control of the treatment processes, the extent of removal of pollution from the raw waste, and conformity of the final effluent to the specified standard.

The median and the range of the first 50 samples taken since the plant started operation in May, 1952, are given in Table I, which shows that with a few minor deviations the waste treatment process is consistently producing effluents which conform to the regulatory specifications. The range shows the lowest and highest values, omitting in several cases raw waste results in which the sample was determined to be not representative. The specifications to be met by the treatment process are given as those established for the final effluent discharged to the Trenton sewer system.

In all cases the filter effluent median is in conformity to the general average specifications. In all determinations except pH, the filter effluent range also conforms either to the specified average or to the one-shift maximum.

Efficiency of Pollution Removal

The amount of oil and suspended solids entering the manufacturing plant process waste is the amount to be removed by the treatment system. The efficiency of the removal is indicated by the percentage of reduction of the polluting materials. Experience with the Colloidair separator when used to process oily wastes at this plant shows satisfactory reductions in the pollution (Table II), the values being based on the medians given in Table I. The chemicals used in the Trenton plant are given in Table III. The preparation of solutions and of the colloidal silica dispersion is done by the regular operator.

Chemical Costs

Current usage shows chemical costs of about $0.12 per 1000 gal. of waste processed. About $0.02 of this total represents the cost of the sodium aluminate used to increase the pH of the final effluent to the desired range. For this purpose a cheaper material is

TABLE II.—Oil Treatment Efficiencies

Treatment	Removal of Oil (%)	Removal of Susp. Sol. (%)
Separator, with chemical treatment	96.2	98.2
Separator followed by diatomaceous earth filtration	98.85	99.5

TABLE III.—Chemicals Used in Oil Waste Treatment

Chemical	Grade	Purpose
Aluminum sulfate	Commercial, ground	"Breaking" the oil emulsion; formation of aluminum hydroxide floc.
Sodium silicate	Philadelphia Quartz Co. "N" brand	Basis for colloidal silica to assist flocculation; to furnish alkalinity for formation of floc.
Ammonium sulfate	Commercial	Activator for formation of colloidal silica.
Sodium aluminate	33% solution	To control pH.
Diatomaceous earth	Johns-Manville Hyflo Super-Cel	Filter aid.

contemplated, to be applied at a point in the system where it will not interfere with the chemical feed equipment.

Overall Operating Costs

The following represent current operation costs:

	Cost per 1,000 Gal. of Waste
Chemicals	$0.12
Labor	0.255
Power	0.042
Air (negligible)	—
Total	$0.417

The labor cost will be no greater when the separator is operated at its capacity of 400 g.p.m. The present operation is at the rate of 250 g.p.m. It is anticipated that the chemical usage will be decreased as the operators become more experienced in their use and the possibility of lower cost materials have been fully investigated.

Preparation of Activated Silica

Flocculation of the type required for the successful operation of the separator at Trenton depends on the use of a few p.p.m. of a colloidal dispersion of silica as a coagulant aid, prepared as needed from sodium silicate using small amounts of ammonium sulfate as the "activator." The dispersion is usually referred to as N-sol activated silica and is prepared from Philadelphia Quartz Company "N" brand sodium silicate (1)(5)(6).

The action of the ammonium sulfate is to neutralize a part of the alkalinity of the sodium silicate, which then converts to colloidal silica. The neutralized solution is aged to permit the silica micelles to grow or become "activated." The probable reaction is:

$$Na_2SiO_3 + (NH_4)_2SO_4 \rightarrow SiO_2 + 2NH_3 + Na_2SO_4 + H_2O.$$

The resultant mixture is then diluted to a lower silica concentration to stop the growth and to produce a stable dispersion, and to prevent gel formation. The appearance of a slight opalescence is an indication of an activated silica dispersion. The colloidal silica particles possess a negative electrical charge, which attracts positively charged ions such as aluminum. Mutual coagulation occurs and the net effect is the formation of a large, tough, highly adsorbent floc. The applications to water systems and certain industrial wastes have been discussed by Hay (1)(3)(4), Black (2)(7), Merrill (5)(6), and others.

Development Work

As a result of cooperative operational studies between the Plant Engineering Department and the Chrysler Engineering Division, chemical usage has been decreased and efficiency in the reduction of pollution has been improved. Further reduction of chemical usage offers interesting possibilities.

Development work at present is concerned with decreasing the chemical usage to the minimum consistent with good operational efficiency; and with

methods for disposal of grease sludge from the separator.

Summary and Conclusions

1. In the installation described, a pressure-flotation type of separator achieves quantitative separation of an oily waste.

2. The separator is considered as a primary treatment. It is followed by diatomaceous earth filtration using a plate and frame filter, in order to bring the effluent within the specified range of 10 to 30 p.p.m. of oil.

3. Since installation the treatment plant has yielded effluents which have consistently met the high quality specified for industrial waste entering the Trenton, Mich. sewer system. A very satisfactory removal of oil and suspended solids has been achieved.

4. The equipment requires a relatively small floor space. Chemicals used for emulsion breaking and floc formation are inexpensive and commercially available.

5. Operating costs are not considered out of line and definite possibilities exist for lower unit costs at capacity operation of the separator.

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FLOW-THROUGH TREATMENT OF METAL INDUSTRY WASTES*

By Frank J. Hendel and V. T. Stewart

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There is practically no standard design of the waste disposal plants for the metal industry because even two very similar plants may face various problems in which the treated wastes may have to be discharged either to rivers, lakes, small brooks, sanitary sewers, deep wells, lagoons, or refuse areas. Each river may be classified differently and may have different zones —each with different requirements for the industrial effluent. The same applies to lakes and brooks. A brook may be so small that the industrial effluent may change it into a river. Sanitary sewers may lead to different types of sewage works having different requirements for toxic chemicals. Lagoons, deep wells, and refuse areas present a danger of seepage of toxic materials to rivers, lakes, and potable wells. In some cases, none of the above listed conveniences are economically possible and one must resort to barging out to open sea or even to a full evaporation.

On top of this, different chemical composition of the wastes, different draining schedules, financial resources of the manufacturer, time of delivery of equipment, and urgency of the problem have to be considered. All this proves that each waste disposal plant has to be designed individually.

Three examples are cited to show how these problems have been solved, using a flow-through system. The phrase "flows-through system" may need some explanation. The description "batch process" is clear. A "continuous process" means that derivatives with respect to time are constant at any point, or that operating variables are held to a steady value. Neither of these designations apply to the system under discussion. The equipment is performing different operations at different times and there are wide variations in the rates of flow. Furthermore, the equipment was designed in such a manner that additional corrections of the liquors may still be made in each holding tank.

The flow-through system is especially economical for large quantities of wastes and where space is limited.

Treatment of Wastes to be Discharged to the River

In one plant the manufacturing stock is plain carbon steel and brass; but the operations include pickling, phosphate coating (Foscoating or Bonderizing), lubrication with special soaps for drawing, varnish stripping, and washing with special detergents. The waste waters carry sulfuric acid, caustic soda, silicates, phosphates, soaps, and detergents. The metal ions present are sodium, ferrous iron, ferric iron, hexavalent chromium, zinc, and copper.

The large volume of wastes from these processes could not be handled, even after treatment, by the municipal sewer of a small town. So it became necessary to provide suitable treatment such that the treated water would meet the requirements of Zone 2 of the Delaware River. These particular requirements have been discussed by Milligan (1).

* Presented in part at 123rd National Meeting, American Chemical Society; Los Angeles, Calif.; March 17, 1953.

The various processing tanks all discharge into one chemical sewer made of vitrified clay pipe. The line discharges into an acid-proof sump that is low enough so that the sewer will drain itself. The alkaline processing tanks are drained on a nightly schedule and the acid tanks on a weekly one as required by the production schedules. Alkaline and acid rinses flow continuously to the sewer, however, during week days.

Acid Solutions

From the sump, the acid solutions are pumped at a steady rate into a bottomless neutralization tank located in one corner of the lagoon. This tank is provided with an agitator and a pH meter. Lime slurry comes through a control valve from the lime slaking equipment, which comprises unloading equipment, silo, feeder, slaker, and storage tank, and which produces a 10 per cent milk of lime slurry. The pH controller and a control valve admit the proper amount of slurry into the bottomless neutralization tank to hold the pH between 7.0 and 8.0. Neutralized liquors, together with all precipitated solids, underflow from this tank to the lagoon. This procedure prevents the formation of any gypsum in the sump where it would be more or less of a nuisance.

The foregoing describes the treatment of the pickling acid wastes, where concentration varies from 10 to 15 per cent of H_2SO_4 plus some phosphoric acid and ferrous and zinc cations.

At other times acid rinse waters are discharged from the plant. These wastes are much larger in volume than the volume of the pickling acid and carry only small amounts of acids, although these amounts are still enough to require neutralization. The equipment is operated in the same manner, except that larger pumps are used.

Alkaline Solutions

When the solution entering the sump is alkaline, sulfuric acid is used for neutralization directly in the chemical sump (Figure 1). This acid is pumped through its own control valve. Since nearly all of the constituents of the alkaline wastes and their neutralization products are soluble, there is no problem of great amounts of precipitate forming in the sump. Besides, the agitator in the sump keeps the solids in suspension while the liquors from the sump are pumped to the lagoon.

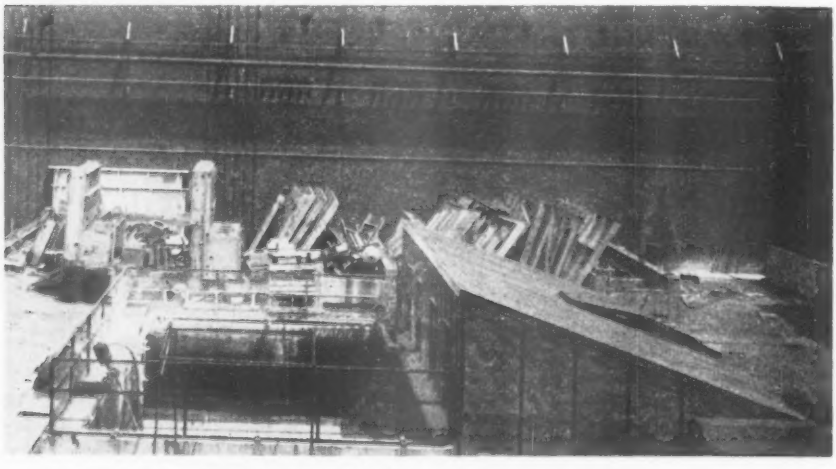

FIGURE 1.—Chemical sump and pump house.

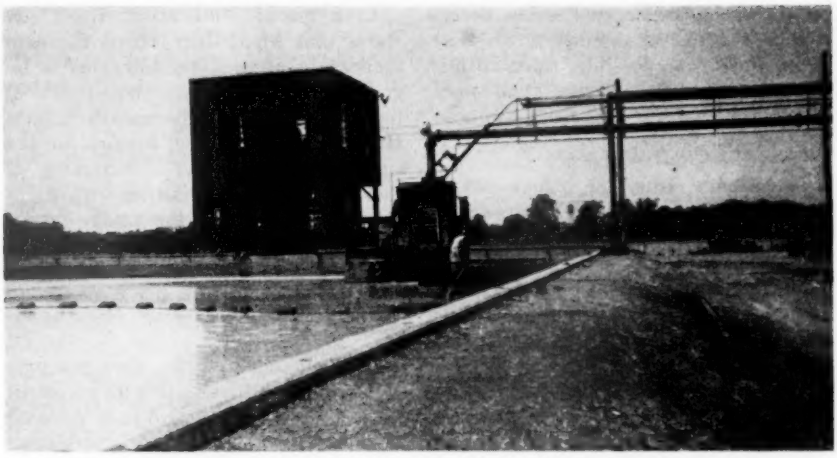

FIGURE 2.—Corner of concrete lined lagoon, showing overhead pipes from chemical sump to aerator, dredging boat with floating discharge hose, and sludge.

Since these operations are not simultaneous, it is convenient to use one pH recorder-controller with two assemblies of electrodes and control valves. One assembly handles lime slurry in the bottomless neutralization tank and the other handles sulfuric acid into the chemical sump.

The amount of sulfuric acid needed for neutralization is very small. Hence, it was considered unnecessary to have large holding tanks where alkaline and acid wastes will partly neutralize each other.

Aerator

On the top of the bottomless receiver is located a wooden aerator (Figure 2), where the liquid splashes and cascades over the baffles while air enters through the louvers. The purpose of this aeration is to oxidize green ferrous hydroxide to brown ferric hydroxide, which will settle much faster in the lagoon. The large surface of the lagoon also aids the oxidation reaction.

Lagoon and Filter

It is highly unsatisfactory to depend upon seepage from a lagoon or pond for the disposal of solutions, as these solutions may make trouble for the neighbors. In the case under discussion the lagoon is lined with reinforced concrete to prevent seepage, and hence it is actually a large sump. The detention time of the liquors is 1 to 2 days. The precipitate, consisting mainly of gypsum with small amounts of ferric hydroxide, calcium phosphate, iron phosphate, copper, chromium, zinc hydroxides, and other constituents, settles to the bottom. Several retention baffles arranged across the lagoon and extending only 3 ft. above the bottom divide the lower part of the lagoon into several compartments. The closer the compartments are to the bottomless receiver the more sludge is found in them. From time to time the sludge is dredged out by a gasoline pump located on a rowboat. The sludge is delivered through a hose connection to a surge tank and thence to a rotary vacuum disc filter, covered with Vinyon-N-719 filter cloth. The overflow from the surge tank and the filtrate flow back to the lagoon. There is no need of producing a perfectly clear filtrate. The filter cake is trucked away and used as fill.

Consideration was given to installing mechanical scrapers to continuously move the sludge to the pump feeding

the filter. However, due to the necessity of starting up the waste disposal plant as soon as possible, the continuous scraping method was abandoned and batch dredging was decided upon.

Oil and pH Control

The effluent from the lagoon passes through an oil separator (Figure 3) so that no oil can reach the river. Part of the effluent is used for slaking the lime. The effluent pH is recorded automatically and the charts are kept available for the inspectors of the Department of Health.

In case the pH of the lagoon water should get out of bounds, arrangements have been made to close the outfall of the lagoon and recirculate the solution. The recirculation line extends from one corner of the lagoon, through a pump, to the opposite corner. Meanwhile, the level in the lagoon will rise, due to the influx of fresh wastes. Recirculation and pH adjustment has to be done within a maximum of 12 hr. in order to prevent the lagoon from overflowing.

In a recent publication, Hoak (2) states that when slurry from the neutralization of pickling solutions is lagooned, it is generally not practical to draw off the supernatant liquor. However, in this case, because of the simultaneous aeration and mixing of the waste pickling solution with high-calcium lime slurry, the sludge settles satisfactorily. The effluent from the lagoon is clear and meets the specifications for discharge to the river.

Chromium

Hexavalent chromium does not present any difficulties in this metal plant. The amount is small and it is reduced to the trivalent form by the addition of spent pickling acid. The ferrous sulfate is the reducing agent. A sufficient quantity of the waste pickling acid is dumped into the process tank and stirred for 30 min., which is sufficient time to complete the reaction. Only then is the liquid discharged to the chemical sewer.

Where chromic acid solution is very dilute the process tanks are made of

FIGURE 3.—End of the lagoon with oil separator during construction. The lagoon is being filled with water to avoid cracks in the concrete lining.

carbon steel. In such cases, waste pickling acid cannot be used, as it would corrode the tank. Sodium bisulfite in powder form or ferrous sulfate is used instead.

Varnish Stripping

Two alternate processes are used for varnish stripping. One uses hot solution of sodium hydroxide, detergents, and chromic acid, while the other uses a medium that contains cresylic acids. In the latter case the wastes containing cresylic acids are pumped directly from the process tanks and after the addition of naphtha or kerosene are burned off in a pit. There is no possibility of cresylic acids reaching the river.

Soap Solutions

Lubrication for the cold drawing of steel is carried out with hot concentrated soap solutions. These solutions are seldom discharged. To prevent congealing of the soap in the sewer and the sump, special precautions are necessary when draining the soap tanks. The soap solution is washed down with large quantities of water. Of course, this requires additional lime in the bottomless receiver of the lagoon to precipitate calcium stearate from the solution.

Treatment of Wastes to be Discharged to the Sewer

In another plant, the waste disposal problem was quite different. This was a substantial electroplating plant located on a site where the only available exit for waste waters was the municipal sewer. The capacity of this sewer was much less than might have been desired, so every effort was made to reduce the volume of wastes at the source by the use of the three rinse tank system, described elsewhere (7). The volume of the wastes was reduced approximately 20 times.

After negotiations, the Rahway Valley sewage treatment plant agreed to accept plant effluent meeting the following specifications:

Cations:		
Cadmium	not more than	3 p.p.m.
Chromium, hexavalent	not more than	3 p.p.m.
Copper, as Cu^{+} or Cu^{++}	not more than	1 p.p.m.
Gold	not more than	3 p.p.m.
Nickel	not more than	10 p.p.m.
Silver	not more than	3 p.p.m.
Rhodium	not more than	3 p.p.m.
Zinc	not more than	3 p.p.m.
Anions:		
Chlorides, as Cl^{-}	not more than	400 p.p.m.
Cyanates, as CNO^{-}	not more than	200 p.p.m.
Cyanides, as CN^{-}	not more than	1 p.p.m.
Fluorides, as F^{-}	not more than	6 p.p.m.
Phosphates, as PO_4^{---}	not more than	20 p.p.m.
Gases:		
Ammonia	not more than	2 p.p.m.
Chlorine, residual	could be more than	5 p.p.m.
Hydrogen sulfide, Nitrous oxides, Sulfur dioxide	total not more than	10 p.p.m.
Organic Compounds:		
Phenol	none	
Solvents and oils	none	
Sulfonated castor oil	not more than	15 p.p.m.

Other Conditions:

(a) pH—7.0 as a daily average on a volumetric basis, with a maximum monetary variation of pH 6.0 to 10.0.
(b) Temperature within the range of 32° to 150° F.
(c) The amount of insoluble substances temporarily not to exceed 2,500 p.p.m., or at a daily average 500 p.p.m.
(d) Total solids (soluble or insoluble substances) temporarily not to exceed 20,000 p.p.m., or at a daily average 2,000 p.p.m.
(e) Insoluble substances not to have a specific gravity greater than 1.5 or be larger than ½ in.

These conditions, as far as chromium, copper, and cyanides are concerned, are even more stringent than those listed by Watson (3), who compiled specifications from ordinances of different cities.

It is worth quoting Dodge and Reams (4) that "certain bacteria are apparently aided by the presence of cyanides," and Ingols and Kirkpatrick (5) that "bacteria can tolerate high concentration of chromium where large amounts of organic matter are present."

In this design of the treatment plant all oily wastes from lacquer stripping, paint spraying, and degreasing are collected in barrels and dumped into an open pit, where after addition of naphtha or kerosone they are destroyed by burning.

Waste Segregation

All other wastes, which are by far the larger part, are segregated into one or the other of two sumps. All wastes from chromium and nickel plating, from pickling with sulfuric and hydrochloric acids, are discharged through one sewer into sump No. 1. All wastes from copper, silver, cadmium, brass, bronze, gold, and rhodium plating, from nitric acid pickling, and from the laboratory are discharged through the other sewer into sump No. 2. The outlet and all inlets of this sewer are trapped to prevent hydrocyanic acid, if evolved in the sewer, from reaching the air.

Acid and Chrome Wastes

Liquors in sump No. 1 are acid and contain hexavalent chromium, which has to be reduced. Part of the chromium will be reduced by the ferrous sulfate present in the pickling wastes. Further reduction is carried out by sulfur dioxide.

The sump is provided with a suitable agitator and an oxidation-reduction recorder-controller. Details of a similar system using ferrous sulfate for reduction have been described by Koerner (6). Although the reduction with sulfur dioxide may be carried out without the presence of other acids, their presence is necessary to prevent the fouling of the electrodes, which will occur when chromium hydroxide begins to precipitate.

Cyanide Wastes

The liquors in sump No. 2 contain cyanides, which have to be destroyed by oxidation. This is carried out by chlorination at pH 8.5 to 9.0.

The detention period in sump No. 2 is several hours using, at the same time, an excess of chlorine. It means, of course, some waste of chlorine, which reacts rapidly with ammonia present in small amounts in the liquors, and also with any cyanates.

Full destruction of cyanates by chlorination requires about 1 hr. at 70° F. If this reaction had to be carried to completion, the chlorine consumption would be approximately 7 lb. per pound of sodium cyanide.

Sump No. 2 is provided with automatic oxidation-reduction control equipment for the chlorine feed line and automatic pH control equipment for the line which supplies sodium hydroxide solution by gravity.

Some hydrated lime in powder form is added manually to this sump once or twice every hour. Lime reacts with complex tartrates, which prevent proper oxidation of copper cyanides. The pH level is mostly maintained by sodium hydroxide. Thus, very few solids are precipitated in the sump. The agitator in the sump keeps the solids in suspension.

The outlet valves of both sumps will close if anything goes wrong with the automatic controls. The level of the wastes in the sumps may rise for a few hours while reduction of chromium and oxidation of cyanides are carried out manually. Manual operation of the sulfonation and chlorination reactions means that excessive amounts of the addition reagents are always used and should be avoided as much as possible.

Lagoon

After completion of these operations outlet valves from the sumps are opened and the batches dumped. The effluents from both sumps flow to a bottomless receiver located at one end of the lagoon. This receiver is formed by a wooden partition, which does not extend quite to the bottom of the lagoon. The effluents are allowed to neutralize each other to the extent possible. A pH recorder-controller admits powdered hydrated lime from a feeder to adjust the final pH between 7.0 and 8.0. The agitator in the receiver provides good mixing before the wastes flow under the partition to the lagoon.

The concrete lined lagoon provides a retention time of 24 hr. whereas the electroplating plant discharges wastes only during the day. Any additional treatment of the lagoon waters, if required, must be done at night. This treatment may be carried out by recirculation from the end of the lagoon to the first or second sump, where additional chlorination, sulfonation, and pH adjustment take place. Only after the lagoon waters are passed by the chemist may the outlet valve from the lagoon to the municipal sewer be opened.

As a safety measure, the effluent from the lagoon passes through an oil separator although, as previously mentioned, no oils or solvents, are discharged to the waste disposal plant.

The municipal authorities allow discharge of a limited amount of sludge into the sewer. To keep within this restriction, sodium hydroxide and only very little lime is used for neutralization. To keep the sludge in suspension while the lagoon is being drained, a recirculating pump takes suction from one corner of the lagoon and discharges to the other three corners.

To provide for expansion, arrangements were made for the future installation of a filter, should the volume of sludge become too burdensome for the municipal sewers.

The procedure will be as follows: while the lagoon liquors are being recirculated, part of the liquors will be drawn off from the recirculation line and forced through a filter press. From the press, the filtrate will go directly to the sewer. The filtrate may, of course, be quite turbid.

Evaporation of Wastes

A third metal working plant was compelled by the state authorities to close down its electroplating department because the requirements for the treated effluent could not be met. Subsequently the rinsing operations after each plating tank were changed to a three rinse tank system. This reduced the volume of the wastes about 15 times, so that evaporation to dryness was economically feasible.

The wastes from the electroplating department are made slightly alkaline, separated from the oily layer, filtered, and concentrated to one-third the volume in a compression distillation unit. The concentrated effluent is finally evaporated to dryness in a spray drier,

so that a small quantity of powder of different metal salts results. The condensate from the compression distillation is really distilled water and is returned to the production area.

A plate and frame filter press is used. It has bottom feed and top discharge and is precoated with diatomaceous earth. Vents in the frames allow the removal of air pockets and improve the precoating.

Operating Costs

The operating cost of distilling 1,000 gal. of water by compression distillation is $3.50 to $4.00, assuming that the cost of energy is $0.01 per kilowatt-hour.

Although the operating cost in a conventional three-effect evaporator is not higher, the need of a steam boiler increases the cost of a waste disposal plant.

Operating costs for evaporation by spray drying or by submerged combustion is more than $10.00 per 1,000 gal.

Frothing and Flue Gas Scrubbing

Some trouble was experienced from frothing caused by the presence of sulfonated castor oil, which had been used as a detergent. The addition of minute quantities (20 p.p.m.) of "DC Antifoam A" emulsion (made by Dow-Corning Corp.) to the feed prevented the frothing.

The flue gas from the spray dryer passes a water scrubber, which removes entrained poisonous dust. Concentrated liquid from the compression distillation still is used for scrubbing. Thus, no additional water is required and the feed to the spray dryer is preheated.

Summary

Three recent designs of the different waste disposal plants for the metal industry are discussed. In one case the treated effluent goes to the river, in another it goes to the municipal sewer and in another it is fully evaporated.

The flow-through process uses automatic equipment for neutralization of acids by lime or soda, reduction of six valent chromium by sulfur dioxide, and oxidation of cyanides by chlorine.

The flow-through process is so adapted that in an emergency it can be changed to a batch process.

Acknowledgment

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TOXICITY THRESHOLDS OF CERTAIN SODIUM SULFONATES FOR *DAPHNIA MAGNA* STRAUS

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The investigation reported herein was carried out to determine the toxicity thresholds displayed by *Daphnia magna* to various sodium sulfonate compounds and to attempt to relate the obtained values with some molecular property. Such information should prove valuable for future investigations of these compounds, as some members of this series are thought to be present in effluents of various industries and are finding widespread use in the field of synthetic detergents.

Although preliminary work (3) on the toxicity of certain sodium sulfonates to the bluegill, *Lepomis macrochirus* Raf., indicated that these compounds are relatively non-toxic to the test animal employed, even at moderately high levels, it was felt that an evaluation of these compounds by means of the daphnid was advisable, as daphnids and other small crustacea are an important fish food, and Anderson (2) has shown that *Daphnia magna* is more sensitive to chemicals than are fish.

Material and Methods

A survey of the literature concerned with the measurement of toxicity tolerances by means of bio-assay methods clearly shows a lack of standardization of the methods employed. It is of prime importance that the results obtained on pure compounds be readily reproducible by other workers regardless of the location of the laboratory. Hence, the author has attempted to employ such methods as might make it possible for other workers to duplicate or to evaluate the results obtained in the light of other work.

Chemicals Tested

This investigation is limited to one series of organic compounds, the sodium sulfonates. Many of the compounds tested were selected on the basis of their molecular structure without regard to the possibility of their being present in any industrial effluent.

All of the sodium sulfonate compounds employed were of the purest grade obtainable (95 per cent or greater purity).

Culture Method

Culture of the *Daphnia magna* used in this study was according to the method of Anderson (2) as modified by Freeman and Fowler (4). Culturing by the indicated method yielded broods, averaging 20 young per brood, every 2½ days.

Testing Procedure

The testing procedure employed was that of Anderson (2) as modified by Freeman and Fowler (4).

All tests were conducted for 100 hr., 11 observations being made during the period, the observations being made at intervals in geometrical progression in powers of 1.99. The number of animals alive in each solution was recorded at the time of observation.

After establishment of the limits of toxicity, three experimental tests were conducted over a narrow range of con-

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centrations, the dilution factor for each test being 1.33.

The tests were all conducted at a temperature of 23° ± 1° C.

Calculation of Toxicity Threshold

The toxicity thresholds were calculated according to the method of Anderson (2). As the experiments were carried out in triplicate, the toxicity threshold was calculated for each test and the average of the three then determined.

Results

Five experiments were conducted on each of 10 organic compounds of the sodium sulfonate series. Nine were aromatic sulfonates and one was an alkyl sulfonate.

Of the 50 experiments, 20 (2 per compound) were for the purpose of establishing the toxicity range and 30 (3 per compound) for the establishment of the toxicity thresholds.

The 100-hr. toxicity threshold of each of the three tests on a given compound was determined and the three threshold values were averaged. Similarly, the 100-hr. range (0 to 100 per cent mortality) for each compound was evaluated as the average of the three tests.

The pH of the test solutions at the concentration imparting 100 per cent mortality was also determined.

The average 100-hr. toxicity thresholds, the 100-hr. toxicity ranges, and the pH values of the 10 compounds investigated are given in Table I.

Discussion

Toxicity Threshold and Molecular Structure

Examination of the average toxicity thresholds in Table I shows several relationships between the molecular structure and the toxicity displayed by the sodium sulfonates employed in this study.

Comparison of the toxicity threshold of sodium *n*-butylsulfonate with those of the other compounds tested indicates that the alkyl sulfonates are apparently less toxic than the aromatic sulfonates.

Analysis of the toxicity threshold values for the sodium benzenesulfonates shows that these compounds are not over one-fourth as toxic, on the average, as is sodium naphthalene-β-sulfonate. Similarly, it is to be noted that sodium anthraquinone-α-sulfonate is far more toxic to the daphnid than is the sodium naphthalene-β-sulfonate.

Further examination of the toxicity thresholds of the sodium benzenesulfonates shows that substitution of various compounds on the benzene ring increases the toxicity of the parent compound, sodium benzenesulfonate. Combinations of these radicals further increase the toxicity, as is shown by

TABLE I.—Summary of Results of Toxicity Threshold Determinations for *Daphnia magna*

Compound	Average Toxicity Threshold (p.p.m.)	0% Toxicity (p.p.m.)	100% Toxicity (p.p.m.)	Toxicity Range, 0–100% Mortality (p.p.m.)	pH at 100% Toxicity[1]
Sodium *n*-butylsulfonate	3,380	1,637	7,827	6,190	7.1
Sodium benzenesulfonate	2,840	1,895	8,000	6,105	7.1
Sodium *p*-chlorobenzenesulfonate	2,394	1,687	3,007	1,320	7.1
Sodium *m*-nitrobenzenesulfonate	2,335	1,000	5,618	4,618	8.6
Sodium *p*-phenolsulfonate	1,876	556	5,623	5,067	6.7
Sodium 4-nitrochlorobenzene-2-sulfonate	1,474	318	3,187	2,869	6.9
Sodium 2,5-dichlorobenzenesulfonate	1,468	389	3,890	3,501	7.1
Sodium *p*-bromobenzenesulfonate	523	200	843	643	6.9
Sodium naphthalene-β-sulfonate	135	55	308	253	7.1
Sodium anthraquinone-α-sulfonate	12	10	30	20	7.1

[1] The standard reference water employed for dilution medium had an average pH value of 7.34.

TABLE II.—Molecular Weights and Parachors of Ten Sodium Sulfonates

Compound	Average Toxicity Threshold (p.p.m.)	Molecular Weight	Parachor[1]
Sodium *n*-butylsulfonate	3,380	160.18	327.7
Sodium benzenesulfonate	2,840	180.16	344.6
Sodium *p*-chlorobenzenesulfonate	2,394	214.62	381.8
Sodium *m*-nitrobenzenesulfonate	2,335	225.16	426.4
Sodium *p*-phenolsulfonate	1,876	196.16	364.6
Sodium 4-nitrochlorobenzene-2-sulfonate	1,474	259.15	463.6
Sodium 2,5-dichlorobenzenesulfonate	1,468	249.07	419.0
Sodium *p*-bromobenzenesulfonate	523	259.08	395.5
Sodium naphthalene-β-sulfonate	135	230.23	450.5
Sodium anthraquinone-α-sulfonate	12	310.27	585.4

[1] Calculated on the basis of free sulfonic ions, employing values of the atomic and structural parachors of the molecules.

sodium 4-nitrochlorobenzene-2-sulfonate and sodium 2,5-dichlorobenzenesulfonate.

Toxicity Threshold and Molecular Weight

Upon comparing the molecular weights and the 100-hr. toxicity thresholds of the sodium sulfonates (Table II) it is noted that an exact relationship apparently does not exist. However, upon plotting these two properties (Figure 1) it is noted that a trend is present among the sodium benzenesulfonates as a group, the toxicity tending to increase as the molecular weight increases until a certain level is reached, at which level the relative change in molecular weight need be rather small in order to produce a

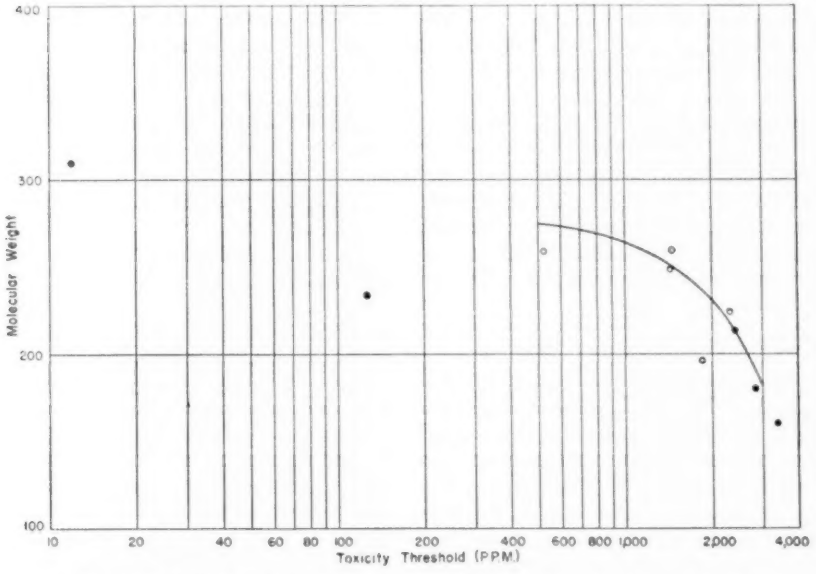

FIGURE 1.—Molecular weight *vs.* 100-hr. toxicity threshold (p.p.m.) of ten sodium sulfonates.

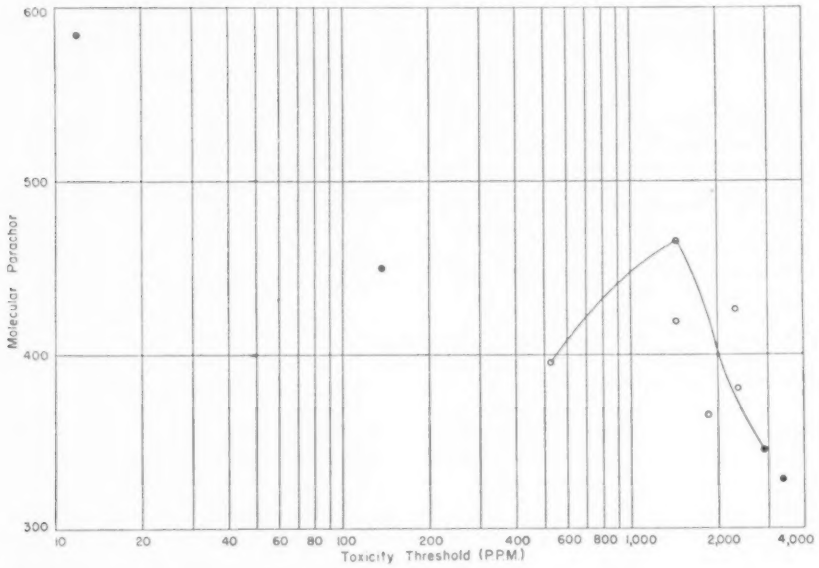

FIGURE 2.—Parachor *vs.* 100-hr. toxicity threshold (p.p.m.) of ten sodium sulfonates.

marked change in the toxicity threshold.

Another interesting relation exists between the *n*-butyl-, the benzene-, the naphthalene-β-, and the anthraquinone-α-sulfonates (solid points, Figure 1). It is seen that an almost direct relationship exists between the aromatic sulfonates, with a marked drop for the alkyl sulfonate's value. Whether this relation is attributable to the increasing molecular weight or to the increasing volume of the molecule can be determined from the parachor values of the molecules.

Toxicity Threshold and Parachor

Examination of the values for the parachors of the sodium sulfonates, Table II, and the plotting of the parachor and the 100-hr. toxicity threshold (Figure 2) shows a peaked curve for the benzenesulfonates and a straight line for sodium benzenesulfonate, sodium naphthalene-β-sulfonate and sodium anthraquinone-α-sulfonate, with a marked drop for the alkyl sulfonate, sodium *n*-butylsulfonate (solid points, Figure 2).

Since almost the same type of curve is displayed for the three different kinds of aromatic sulfonates as was displayed when the molecular weight was employed (Figure 1), it may be assumed that the volume of the molecule, rather than the molecular weight, was the determining factor in the toxicity displayed by these three types of compounds.

The benzenesulfonates display a definite trend towards increasing toxicity with increasing values for the parachor. An exception is sodium *p*-bromobenzenesulfonate, as this compound shows a definite increase in toxicity even though it has a lower parachor value than several of the other sodium benzenesulfonates. This deviation, together with the slight variation in toxicity with increasing parachor values displayed by the other benzenesulfonates, may be indicative of the importance of the substituted group, and this factor may outweigh any effect

imparted by increasing the molecular size or the molecular weight.

Toxicity Threshold and pH

The sodium sulfonates apparently do not belong to those compounds that exert their effect through a change in the pH, for the pH values (Table I) were within the limits of tolerance of *Daphnia magna*, these limits being about 6.0 to 8.7 with an optimum at about 7.4 (1). The compounds, then, probably belong to the truly toxic group or the osmotically modifying group, but no information was gathered in this study on the osmotic pressure displayed by the concentrations of sodium sulfonates employed.

Conclusions

1. Ten sodium sulfonates were bioassayed with *Daphnia magna* and their 100-hr. toxicity threshold, 100-hr. toxicity range, molecular weight, molecular parachor, and pH at the 100 per cent toxicity level are reported.

2. The more complex the ring structure of the aromatic compounds, the more toxic are the compounds; thus, in order of increasing toxicity: benzene, naphthalene, anthraquinone.

3. Substitution of various groups on the benzene ring increases the toxicity, *p*-bromine imparting the greatest toxicity, followed by 2,5-dichloro, 4-nitrochloro-2-, *p*-hydroxyl, *m*-nitro and *p*-chlorine substitution.

4. Analysis of the data on the basis of molecular weights yields two conclusions: the toxicity of the sodium benzenesulfonates tends to increase as the molecular weight increases until a level is reached, at which point the toxicity increases more rapidly than does the molecular weight; a direct relation exists between an increasing number of rings, with a corresponding increase in molecular weight, and the toxicity.

5. The parachor data indicate: the sodium benzenesulfonates display a trend towards increasing toxicity with increasing values of the parachor; a direct relation exists between an increasing number of rings and the parachor; the increase in toxicity with increasing number of rings is attributable to the volume of the molecule rather than the molecular weight; and the nature of a group substituted on the benzene ring may be of more importance than the size of the molecule or its weight.

6. The toxicity of the sodium sulfonates to *Daphnia magna* is not attributable to any effect the compounds may have on the acidity or alkalinity of the test solutions.

Acknowledgments

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Stream Pollution

OCEAN OUTFALL STUDIES AT SAN DIEGO*

By Frank J. Kersnar and David H. Caldwell

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San Diego County borders the Pacific Ocean in the extreme southwestern corner of the United States. The coast line extending from the Mexican border northward for 70 mi. is a continuous series of sandy beaches and high bluffs broken by rivers, bays, and lagoons. Because of ideal living and working conditions, development of the coastal area has been rapid, until more than 500,000 people reside there today. The area will undoubtedly continue to grow and a population of over 3,000,000 by the end of the century is predicted.

Realizing the need for a comprehensive study of the sewerage problems and for the development of a long-range plan for the sewerage of San Diego County, the Board of Supervisors on August 21, 1951, appointed a Board of Consulting Engineers, consisting of A M Rawn, C. G. Hyde, and D. H. Caldwell, to conduct the San Diego County Sewerage Survey.

Factors Affecting Ocean Disposal

The volume of sewage which can be sucessfully disposed of at a particular point in ocean water is directly related to the ocean's ability to dilute the sewage, to destroy pathogenic organisms, and to oxidize organic matter. The known factors are:

1. Temperature structure, obtaining particularly from early spring to late autumn, which indicates a temperature difference from the ocean floor to its surface of 8° to 10° F.

2. Favorable currents attaining velocities such as to prevent the deposition of suspended solids contained in the sewage or sewage effluent.

3. A depth at the point of outfall sufficient, with appropriate design of the outlet structure, to result in great dilution of the sewage effluent before the mixed effluent and sea water reaches the ocean surface.

4. Solid anchorage or the ability to secure solid anchorage of the outfall pipe through the breaker zone and into water of 40- to 50-ft. depth.

5. Isolation from beach areas to insure protection from contamination or nuisance.

When sewage or sewage effluent is discharged below the ocean surface, it tends to rise immediately because of its lesser specific gravity. The initial energy imparted to the sewage is usually not dissipated, even with the admixture of large quantities of sea water, until the mixed liquid reaches the surface. At that point one of two general phenomena will occur. Either the sewage-sea water mixture will immediately submerge and disappear, or it will float and spread over the surface. The first phenomenon results from the discharge of sewage into sea water which is considerably colder than the surface water. In rising, the sewage or sewage effluent mixes with this colder water until, by the time the mixture reaches the surface, its tempera-

* Presented at 25th Annual Meeting, California Sewage and Industrial Wastes Assn.; Santa Barbara, Calif.; April 22–25, 1953.

ture is lower than that of the surrounding ocean water and its density is greater. An unstable condition exists, therefore, and the denser sewage-sea water mixture will submerge. The second phenomenon, where the sewage-sea water mixture spreads laterally over the surface of the ocean, occurs when the sewage effluent has been discharged into water only slightly colder than the surface water. By the time the sewage effluent reaches the surface, although it has become mixed with sea water in rising, its temperature has not been lowered below that of the surrounding ocean water and its density will be equal to or lower than that of the surface water. The mixture, therefore, will float and will move with the surface currents, at the same time continuing to diffuse and to mix with greater quantities of sea water. After an interval of less than 1 hr. to more than 3 hr., depending on the initial dilution achieved, all traces of sewage will have disappeared.

Field Studies

To determine the suitability of the ocean off San Diego County's coastline for sewage disposal, field studies involving the collection of current and temperature data were conducted at three selected locations (Figure 1). These data are believed to reflect conditions existing along the entire coastline of San Diego County. Because of a similar coastline between Oceanside and Del Mar, the data collected in the Oceanside-Carlsbad area are believed to be applicable to that entire stretch of coast. The data collected in the Point Loma area are believed to be applicable to that portion of the coastline only, since the configuration of the ocean shore from Point La Jolla to the entrance into San Diego Bay is such that ocean conditions existing there are peculiar to that area. Data collected in the Imperial Beach area are believed to be applicable to the coastline from Silver Strand to the Mexican border.

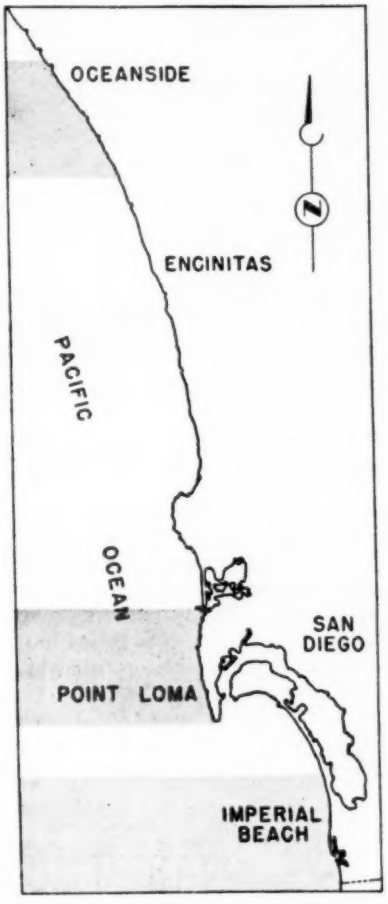


FIGURE 1.—Location of areas of ocean study, San Diego County.

Temperature Structure

The initial dilution that occurs when sewage effluent reaches the surface depends to a large extent on the temperature structure of the water through which the sewage effluent passes in rising. Determinations of the temperature structure of the ocean adjacent to San Diego County were made by the use of bathythermographs loaned to the survey by the Scripps Institution of Oceanography and by the Oceanographic Branch of the U. S. Naval

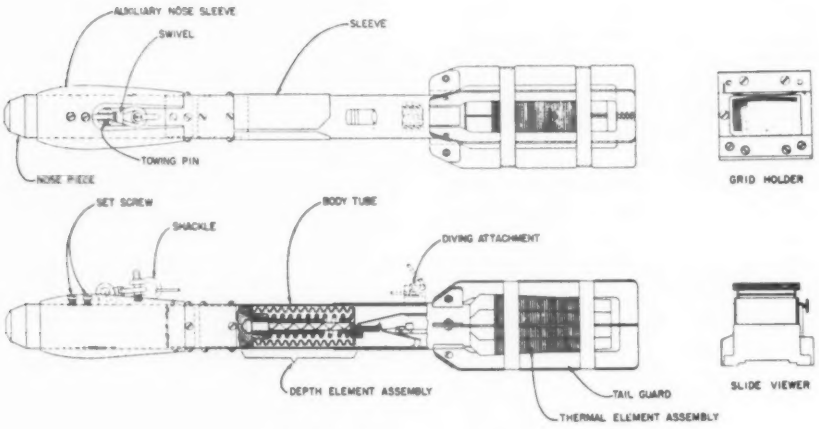


FIGURE 2.—Bathythermograph.

Electronics Laboratory. The bathythermograph (Figure 2) is an instrument for obtaining a permanent graphical record of water temperature *versus* depth. The instrument is lowered to the ocean floor and raised to the surface by a wire cable operated by a winch mounted on a boat. The temperature record is made by a stylus giving a continuous trace on a smoked glass slide. Bathythermograms were taken on lines approximately normal to the ocean shore. A typical series consisted of nine traverses taken at intervals of 1,500 ft. from about 2,000 ft. to 15,000 ft. from shore. The temperature-depth records thus obtained were used to prepare a temperature profile (Figure 3) showing the vertical distribution at the time each series was taken. Bathythermogram series were run morning and afternoon on each

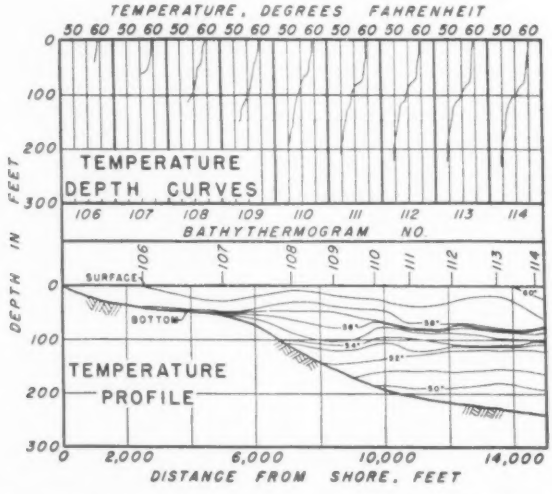


FIGURE 3.—Typical ocean temperature profile off San Diego County.

day during which ocean studies were made. A total of 22 such series was run in the Point Loma area, 5 in the Oceanside-Carlsbad area, and 4 in the Imperial Beach area.

Higher temperatures prevailed at and near the ocean surface during afternoons as compared to mornings of the same day, due to the warming effect of the sun. The change or displacement of the isothermal lines may be partially attributed to the mass movement of water due to ocean currents. On a rising tide, the mass of water which has moved toward shore is warmed because of the shallow depth and the existence of more turbulent conditions along shore. As the tide falls, a portion of this water returns seaward as a surface layer because of its higher temperature and lesser density. This increases the volume of warm water near the surface and results in a downward displacement of the isothermal lines.

In all the areas studied, a great variation in temperature structure was noted throughout the year (Figure 4). During the summer months air temperatures are higher and the period of daylight during which the water can be warmed by the sun is greater than during the winter months. This results in higher water temperatures near the surface of the ocean and increases stratification. The maximum difference in temperature between the ocean floor and the surface was 18.5° F. and occurred on July 28, 1952. Temperature differences greater than 8° F. were observed from about the middle of April to the first of November. As the air temperature and the hours of daylight decrease during the winter months, stratification also decreases, and vertical mixing due to convection increases. It is possible for the ocean temperatures to be almost uniform from surface to botton. Such a condition occurred on January 14, 1952, when a temperature difference of only 0.8° F. was observed.

The temperature structures of the ocean at all three areas were found to be similar. In this respect, conditions for ocean disposal of sewage would be the same in each area. In the Imperial Beach area, however, initial surface dilutions could not be expected to be as high as in the Point Loma or Oceanside-Carlsbad areas, because the depth at any reasonable distance from shore is much less than in either of the other areas.

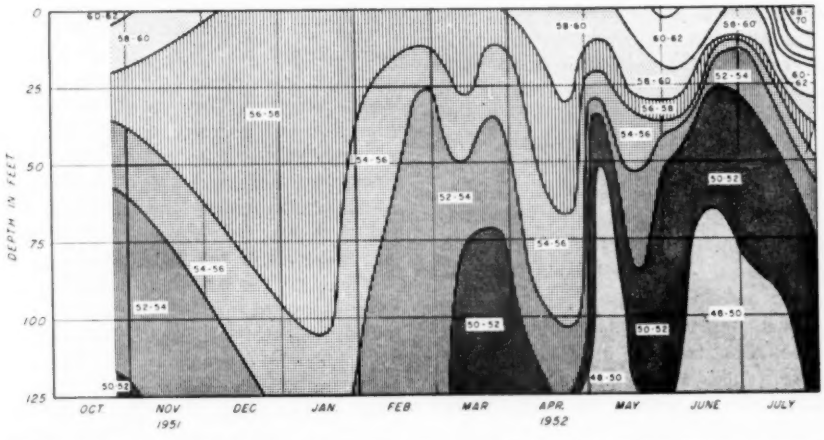


FIGURE 4.—Monthly variation in ocean temperature structure off San Diego County.

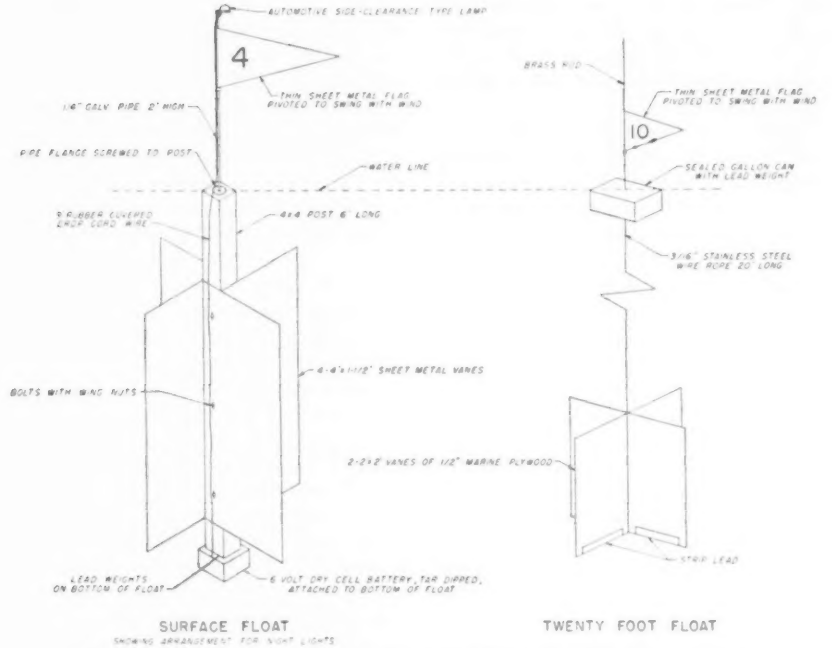

AUTOMOTIVE SIDE-CLEARANCE TYPE LAMP
4
THIN SHEET METAL FLAG PIVOTED TO SWING WITH WIND
1-1/2" GALV. PIPE 2' HIGH
PIPE FLANGE SCREWED TO POST
WATER LINE
RUBBER GROMMET
4x4 POST 6' LONG
BOLTS WITH WING NUTS
LEAD WEIGHTS ON BOTTOM OF FLOAT
6 VOLT DRY CELL BATTERY, TAR DIPPED, ATTACHED TO BOTTOM OF FLOAT
SURFACE FLOAT
SHOWING ARRANGEMENT FOR NIGHT LIGHTS
BRASS ROD
THIN SHEET METAL FLAG PIVOTED TO SWING WITH WIND
10
SEALED GALLON CAN WITH LEAD WEIGHT
3/16" STAINLESS STEEL WIRE ROPE 20' LONG
2-2'x2' VANES OF 1/2" MARINE PLYWOOD
STRIP LEAD
TWENTY FOOT FLOAT

FIGURE 5.—Details of surface and depth floats used in current studies.

Ocean Currents

If or when the dispersed and diluted sewage effluent reaches the ocean surface and stratifies, its movement is controlled by the surrounding surface currents. The survey's study of ocean currents was made primarily to determine the velocities and direction of the currents in the transition zone. Currents in this zone result from a combination of various forces usually classed as tidal and nontidal. Tidal currents are produced by the periodic rise and fall of the ocean surface. Nontidal currents may be caused by wind, deep ocean currents, topography of the ocean floor, and variation in sea water density.

Ocean currents off shore from San Diego County were studied by means of free floats. Two types of floats were used, 6-ft. surface floats and 20-ft. depth floats (Figure 5). Each surface float was weighted with lead at its lower end so that it would float in an upright position with its top just above the water surface. The only part extending above the surface was a rod and a sheet metal flag. The flag was free to swing with the wind, hence offering minimum wind resistance. The area of the vanes under the surface was so much greater than that of the rod and flag that the net movement of the float properly represented the travel direction and distance of the 6-ft. layer of water in which it floated. The 20-ft. floats were weighted with sufficient lead to almost submerge the small surface cans. Again, only the rod and pivoted flag were above the water surface.

Float studies at night were accomplished by adding lights to the same surface floats. A small automotive-type side-clearance lamp with a flashlight bulb powered by a 6-v. dry cell battery was mounted on top of the rod. With this arrangement, the lights on top of the floats were visible almost

as far as were the flags in daylight. The 20-ft. floats were not used in the night current studies.

In conducting the float studies, a series of surface floats, usually five, were released about 1,500 to 2,000 ft. apart on a line approximately normal to the shore. Once each hour the position of each float was determined from the boat by moving the boat to the float position and shooting double sextant angles between three control points on shore. The sextant angles were set on a three-armed protractor and the intersection of the three lines connecting the control points was the point from which the angles were shot. By this method, a continuous record of float movements was maintained on the boat (Figure 6).

A total of 23 current studies was made during the course of the survey.

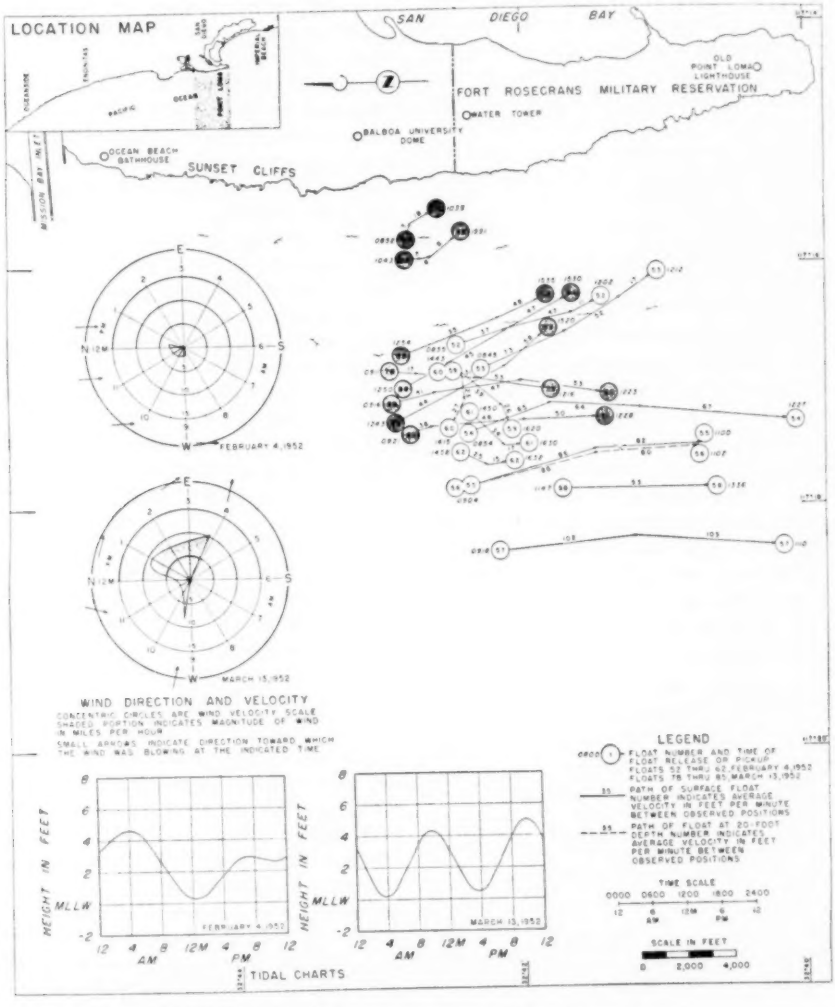

LOCATION MAP
SAN DIEGO BAY
FORT ROSECRANS MILITARY RESERVATION
OLD POINT LOMA LIGHTHOUSE
WATER TOWER
BALBOA UNIVERSITY DOME
OCEAN BEACH BATHHOUSE
SUNSET CLIFFS
MISSION BAY INLET
FEBRUARY 4,1952
MARCH 13,1952
WIND DIRECTION AND VELOCITY
CONCENTRIC CIRCLES ARE WIND VELOCITY SCALE
SHADED PORTION INDICATES MAGNITUDE OF WIND IN MILES PER HOUR
SMALL ARROWS INDICATE DIRECTION TOWARD WHICH THE WIND WAS BLOWING AT THE INDICATED TIME
HEIGHT IN FEET
MLLW
AM
PM
TIDAL CHARTS
LEGEND
FLOAT NUMBER AND TIME OF FLOAT RELEASE OR PICKUP
FLOATS 52 THRU 62 FEBRUARY 4,1952
FLOATS 78 THRU 85 MARCH 13,1952
PATH OF SURFACE FLOAT NUMBER INDICATES AVERAGE VELOCITY IN FEET PER MINUTE BETWEEN OBSERVED POSITIONS
PATH OF FLOAT AT 20-FOOT DEPTH NUMBER INDICATES AVERAGE VELOCITY IN FEET PER MINUTE BETWEEN OBSERVED POSITIONS
TIME SCALE
SCALE IN FEET
0 2,000 4,000

FIGURE 6.—Typical ocean currents off San Diego County.

Of these, 15, including two 24-hr. studies, were made seaward of Point Loma, 3 in the Imperial Beach area, and 5 in the Oceanside-Carlsbad area.

The float studies demonstrated that the ocean currents in the transition zone are of a complex nature and are usually the result of several current producing forces acting simultaneously. Discussions with oceanographers from the Scripps Institution of Oceanography and from the Oceanographic Branch of the Naval Electronics Laboratory led to the conclusion that the available data were insufficient to determine the effect of individual factors such as wind, tide, and deep ocean drift. To accomplish this, it would be necessary to have available almost continuous current observations over a prolonged period of time. Since the primary purpose of the survey's current studies was to ascertain the nature of the currents resulting from a combination of all factors, and particularly to discover whether sewage effluent could be discharged at some determined distance off shore with no resulting contamination of the beaches, it was decided to reduce the current data to terms of maximum shoreward velocities in the area studied. Maximum velocities toward shore determine the minimum time interval required for a given particle of sewage effluent to travel in the surface layer from the outfall point to shore. Such an analysis is believed to be conservative, since the current studies showed that the maximum shoreward component of the velocity did not occur simultaneously at all distances from shore.

Results of these calculations showed that the minimum time of travel to shore from a point 7,500 ft. off shore in the Point Loma area would be 5.2 hr., that the time would be 2.4 hr. from a point 5,000 ft. off shore in the Imperial Beach area, and would be 6.6 hr. from a point 9,000 ft. off shore in the Oceanside-Carlsbad area.

Capacity of Ocean to Receive Sewage

Previous studies (1) have indicated that sewage is not detectable when it has been diluted 225 times with sea water. Using this value as a guide, a study was made of each of the locations along the San Diego County coastline at which it seemed possible that ocean outfalls might be considered. The degree of treatment required at each point was then determined on the basis of the temperature and current data, of the ocean depth at any given point, and of the predicted peak sewage flows. These calculations, plus other controlling factors, such as isolation from beaches and foundation conditions, showed that the most favorable site available in San Diego County for an ocean outfall is the area seaward of Point Loma. If sewage effluent is discharged in this area approximately 7,500 ft. off shore at a depth of 125 ft., no contamination of the shore or shore waters will result, even under the most unfavorable conditions of dilution and currents. Although calculations showed similar conditions along the entire coastline from Del Mar to Oceanside, the proximity of beaches in that area indicates that a higher degree of sewage treatment, including disinfection during critical periods, will be required. The area off Imperial Beach was shown to be unsuitable for the disposal of sewage; if sewage is to be discharged there, a form of secondary treatment, plus disinfection, will be required.

Conclusions

Studies of ocean disposal of sewage reported herein demonstrated the suitability of disposing of the sewage of San Diego County into the Pacific Ocean. Studies of other phases of the sewerage requirements of the county indicated the economy of such disposal. Based on these findings, the Board of Engineers recommended the construction of a primary sewage treatment plant on Point Loma with dis-

charge of effluent to the Pacific Ocean 7,500 ft. off shore in 125 ft. of water. Initially the plant would serve more than 1,000,000 persons, and ultimately more than 2,500,000 persons.

Acknowledgments

Valuable assistance in the form of equipment loans and advice was tendered to the survey by personnel of the Scripps Institution of Oceanography and the U. S. Naval Electronics Laboratory. Acknowledgment is made in particular to Robert S. Arthur and Joseph L. Reid of the Scripps Institution of Oceanography and to Eugene C. La Fond of the Naval Electronics Laboratory.

Reference

1. Rawn, A M, and Palmer, H. K., "Predetermining the Extent of a Sewage Field in Sea Water." *Trans. Amer. Soc. Civil Eng.*, **94**, 1036 (1930).

BUSINESS AND DEFENSE SERVICES ADMINISTRATION SET UP IN COMMERCE DEPARTMENT

Establishment of a new Business and Defense Administration, a primary organization unit in the U. S. Department of Commerce, was announced October 1, 1953. The new agency continues the residual defense and mobilization functions of the former National Production Authority and establishes 25 industry divisions staffed by business experts from government and private industry.

Besides its obvious functions in the area of defense production and planning, the agency is designed to serve business and in many ways stimulate economic growth and stability. In carrying out its emergency responsibilities the new agency is expected to preserve the nucleus of an organization which can be expanded rapidly in the emergency mobilization and the later return to full operation of the free enterprise system.

Also established under the Administration are 25 industry divisions, including one designated Water and Sewage Industries and Utilities. The latter is currently under the directorship of T. T. Quigley, advertising and sales promotion manager of Wallace and Tiernan Co., Inc., who is on loan from his company under the Department of Commerce executive rotation system and had previously served the NPA as a consultant to the Water Resources Division in 1951–52.

The functions of the industry divisions include the following defense and mobilization preparedness activities:

1. Administer the Defense Materials System and take related actions in support of military and atomic energy programs.

2. Review and make recommendations to the Office of Defense Mobilization on expansion goals, tax amortization, and domestic loan applications.

3. Make recommendations on the stockpiling or the disposal of stockpile strategic materials and equipment in relation to industrial requirements to avoid any adverse effects on the national economy.

4. Participate in the development of the Mobilization Base Program for the provision of adequate industrial facilities in the event of national emergency.

5. Provide mobilization authorities with basic data for use in the identification and rating of facilities to be protected against the possibilities of enemy damage.

6. Provide assistance to the Office of Defense Mobilization in regard to participation with industry in post-attack planning.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

A REAL OPERATOR THRIVES ON PROBLEMS

Elsewhere in THIS CORNER there appears a paper meriting the careful attention of operators and superintendents in treatment plants of all types and ranging in size from the largest to the smallest. Reference is made to the article by William J. Ball, in which he presents an excellent example of a case where an industry has incapacitated a municipal sewage treatment plant through ignorance or through insistence on using the municipal facility despite the obvious detrimental effects of such use.

In solving the problem described, pretreatment of the tannery wastes seems worthy of first consideration. Apparently, however, there is more involved than appears at first glance, for the community seemingly is reluctant to push the industry too far in the matter of preparing its wastes for treatment in the municipal plant. Whether the reason behind this reluctance is economic, political, or otherwise does not matter: the reluctance is an ever-present fact.

But this is only the bare story, told in a simple and straightforward statement of facts. The impressive feature is not the magnitude or the complexity of the problems involved, but the cheerful attitude with which the solutions are being objectively sought.

Superintendent Ball is to be complimented for this approach to what is virtually an impossible situation. He has not just given up: he is actively engaged in laboratory and pilot plant investigation to improve the operation of what he has, as well as to prepare for new plant improvements or replacement. In addition he is continuing with his long-range program of industry education to secure the cooperation necessary to eventual success for both his own and the industry's programs.

The philosophy expressed in the last paragraph of Mr. Ball's paper is particularly pleasing to those who know and appreciate the hardships under which municipal sewage treatment plant operation is sometimes carried on. It is, in fact, a philosophy that would bring much satisfaction to many operators and superintendents if they would adopt it instead of continuing to gripe and make alibis for the real or fancied deficiencies of their plants.

Our hats are off to Mr. Ball! By making the best possible use of a plant in an almost impossible situation—and without any alibis—he has found some feeling of satisfaction in a job well done. More than that, he has earned for himself the enviable accolade of "Operators' Operator."

H. P. O.

OPERATION OF INADEQUATE FACILITIES AT BALLSTON SPA, N. Y.*

By William J. Ball

Superintendent, Water and Sewer Department, Ballston Spa, N. Y.

In common with every other sewage treatment plant, that at Ballston Spa, N. Y., has its problems in handling and treating the incoming sewage so that a satisfactory effluent may be discharged to the receiving stream. To understand these problems, however, it is necessary to review briefly the history of the plant, which has considerable bearing on current operation difficulties.

The original treatment plant was started in 1905 and 1906 on a court order to the village of Ballston Spa to treat its sanitary and industrial sewage prior to dumping it into the receiving stream. The plant as then designed included a pumping station to move the sewage to the plant site, a series of septic tanks, a two-stage contact bed for effluent treatment, and underdrained lagoon areas for the sludge. The plant was financed by a $90,000 bond issue sold in 1905 with an approximate interest rate of 4 per cent. The first payment against the principal did not start until 1930, 25 years after the bond issue was sold. The bonds, finally paid up in 1940, cost the village more than twice what the original bond issue was worth.

This kind of financing was probably necessary at that time because in 1899 and 1900 the village had contracted considerable indebtedness by completely rebuilding its water supply and distribution facilities.

It is not hard to see, however, that indebtedness contracted in the manner mentioned would cause hardships in making capital improvements to the plant in later years, which is what happened. Capital improvements were needed before the original bond issue was retired. This meant further indebtedness for the sewer department. In 1930 and 1937, for example, when additions and improvements were made to the sewage treatment plant and its equipment, additional money had to be borrowed to finance the operations. Sections or stages of the old treatment plant were either abandoned or replaced long before they were even paid for.

By 1937 additional pumping capacity was installed, the septic tanks were converted to settling tanks, and one of the tanks had a straight-line sludge collector placed in it. A slow-rate trickling filter was built to replace the old-style contact beds, and the lagoon-type sludge beds were re-built and enlarged.

In 1947 when the trickling filter had started to become inoperative, plans were made to increase the capacity of the filter bed. But the project was stopped before the addition was completed and at present the bed is being utilized, as best possible, as a settling tank.

The treatment plant serves the approximately 5,000 population of the village of Ballston Spa and its industries. The contributed flow is approximately 1.5 m.g.d., but the sludge load is equal to that from a population of 40,000 or more.

Sewage Flow and Character

The sewage received at the plant is made up of:

1. Domestic sewage,
2. Industrial wastes.
3. Storm and cellar drainings.

The domestic sewage from roughly 1,000 buildings of the village does not

*Presented at 1953 Spring Meeting, New York Sewage and Industrial Wastes Assn.; Rochester, N. Y.; June 8–9, 1953.

present too great a problem, despite the innovation of the household garbage grinder.

The industrial sewage consists of the wastes from a tannery, knitting mills, laundries, and milk and creamery plants.

The American Hide and Leather Company, one of the main contributors to the plant, is one of the largest independent cowhide tanneries in the country, with a production capacity of 5,000 sides a day. This means that at peak production 2,500 cowhides can be put into the production system each day, although current operation is at the rate of about 1,250,000 sq. ft. of leather per month. At this production rate, the tannery contributes about 700,000 g.p.d., of which 100,000 g.p.d. comes from the municipal water supply and about 600,000 g.p.d. from the company's private water supply.

The contributed sewage contains salt, manure, etc., washed from the raw hide; 3 tons of lime per day used in de-hairing the hides; some 200 lb. of sulfides; and other chemicals, such as chrome salts, sulfuric acid, basic dyes, and finishing pigments. All of this contributed sewage is passed through a rotary drum screen designed to remove the hide trimmings and hair particles, which are not caught at the machines during production. Because the screen cannot remove all of the solid particles reaching it, a considerable amount of the hair goes on into the sewer system and eventually to the treatment plant, along with the other chemicals, which are in suspension or solution.

The knitting mill wastes consist mostly of soapy wash water, dye solutions, and lint from the wool being washed. The soaps aid in maintaining the high alkalinity of the sewage.

The laundries contribute large quantities of highly alkaline soapy wastes, plus unusual amounts of rinse and wash waters. The milk and creamery plants contribute small amounts of wastes which do not seem to affect the sewage because of the high dilution achieved by the time the sewage reaches the plant.

The sewage flow is also increased by large numbers of open cellar and foundation drains and catch basins that drain off surface waters to the sanitary sewer systems. Because much of the community is without storm-water sewers, there is no place to drain these surface waters but into the sanitary sewer system. In many sections of the village there still exist many storm-water catch basins with their overflows connected to the sanitary sewer system. During a rain, storm flows to the plant may exceed 3 m.g.d.; following wet periods, cellar drainage is estimated to contribute 0.5 m.g.d. over the operating average flow to the plant.

Interceptor Cleaning

The 30-in. vitrified tile interceptor that picks up all the sewage from the village and carries it to the pumping station presents a large maintenance problem to the Department each year. The main, approximately 5,500 ft. long, has to be cleaned at least twice a year in order to handle the flow. About 1,500 ft. is laid under village streets, the remaining 4,000 ft. being laid through gardens, backyards, and swampy low lands, under buildings and two stream crossings. The mains are cleaned with two hand-operated winches pulling an expanding sewer cleaner through the main at least four times, with the cleaning head being opened to various sizes until the full diameter is nearly reached. No effort is made to remove the solids from the line during the cleaning operation, but the cleaning is done during peak flows of the day and the resulting flow agitates and carries the material to the grit chamber and the wet wells, where it is removed.

Much of the solid material removed from the line consists of solidified lime deposits and hair particles, which tend

to cling together to form long, stringy, root-like masses that build up on the inside walls of the pipe or settle to the bottom of the line, unable to move with the sewage until broken up or with unusually high flows. The rest of the material in the line consists of sand and stone dust from the streets of the village and grit from running cellar drains. The sewer cleaning operation is done in cooperation with The American Hide and Leather Company, which pays the labor costs. Although the 30-in. interceptor only requires cleaning twice a year, the mains at the tannery are cleaned 4 to 6 times a year by the same cleaning method.

Since much of the interceptor lies along a sizable stream, which is seriously affected by storm flows, there has been considerable trouble due to washouts of the pipe line at stream crossings or where the line parallels the stream. One such problem was corrected by straightening the stream flow, dredging the stream bed with a bulldozer, filling over the washed out section of the main, and protecting the bank of the stream from further washouts by riprapping the banks with large quarry stone. Another section, still uncovered, is to be repaired by similar means as soon as the wet season is over so that trucks and heavy equipment can be moved into the area.

Grit Removal and Comminution

Solid material is removed from the grit chamber by hand and averages about 4 cu. ft. per day during normal operating conditions. When the interceptor is being cleaned, grit removal averages 20 cu. ft. per day. Grit removal equipment consists of a trash rake with some coarse wire screening fastened to it and an oversize hoe. The grit is hauled by wheelbarrow to a low area adjacent to the pumping station where it is used for fill. When the depth of the grit in the chamber gets to the point where effective settling time for grit is lost, the flow is diverted and the chamber is cleaned by hand. Grit removed at this time amounts to about 40 cu. ft. of sand, lime deposits, and masses of hair and rag materials.

From the grit chamber the sewage flows to a 25-in. comminutor, which has been practically trouble-free except for ocasional excessive flows caused by hard rain storms. This causes large amounts of rags to entangle the comminutor drum and stop it. The situation is quickly remedied by diverting the flow through the bar screens, dewatering the comminutor chamber, and removing the material causing the stoppage.

Pumping

The sewage then goes into wet wells and a 125,000-gal. retention tank, which holds it for long enough periods to make it economical to pump to the treatment plant. Considerable sludge settles out during this holding period and becomes septic, causing odors and quite a nuisance problem at the pumping station. It is fortunate that the station is not located in a populated area. The wet wells were constructed with square corners and a flat bottom, so that the sludge does not get a chance to flow toward the suction pipes of the sewage pumps and be carried to the plant. Attempts are made to agitate the stagnant areas of the wells, but because of the disagreeable features, such as hand agitation and the odors of the pits, the men avoid the job as much as possible. Periodically the wells are drawn down enough so that two or three men can get right into the tanks and flush the sludge to the pump suctions for removal to the treatment plant.

Since only small sections of the plant or pumping station are fenced, there is the problem of property damage from children throwing stones at the building or into the wet wells. It is frequently necessary to remove several wheelbarrow loads of stone and bricks,

which apparently are thrown into the open wet wells just to see the splash. No damage to equipment has resulted from this source as yet, but the source of trouble does exist and money is not available for adequate fencing.

The pumping station contains two 1,000-g.p.m. and one 2,250-g.p.m. vertical sewage pumps. All have given excellent service, the only problem being shaft sleeve wear, apparently due to the large amount of gritty sewage pumped. Various packings have been tried, but conversion of one of the pumps to a clear-water seal to check on difference of wear is under consideration. The job of repairing the pumps is not necessarily expensive, but it does take time from other jobs.

The two force mains from the pumping station are of cast-iron bell-and-spigot pipe, one 12 in. and one 16 in. in diameter. Each line is about 3,000 ft. long. In 1949, when a railroad relocation project crossed the force main, a section of the two mains was relocated. At that time it was found that the two mains were coated on the inside with a ¾ in. thick layer of spent lime or calcium deposits. Since the coating had built up inside one of the lines within a period of 10 years, a check is kept on the flow to determine if this will be the maximum buildup or if a major cleaning project may be required within a few years if the condition continues to grow. At present the only method of restricting the growth is to occasionally allow the pumps to put full flow into one of the lines at a time in an attempt to either scour out the line or to move any loose material that might be attached to the pipe or that might have settled in the line.

Primary Settling

The present primary settling tanks are the septic tanks built in 1905. Two of the tanks are just open tanks with no sludge collecting equipment; one tank is equipped with a straight-line sludge collector. The sludge flows through the three tanks in series, starting with those without the collectors. Each tank is about 110 ft. long, 35 ft. wide, and has an effective settling depth of about 12 ft. Since it has been calculated that the settleable solids average about 35 cu. yd. per day, it only requires about 100 days to fill the two tanks to a point where the detention time is cut down considerably. An attempt is made to maintain long detention periods, as a floc seems to be always forming in the effluent and longer detention allows more of the suspended or dissolved solids to settle.

The first two tanks are generally in a septic condition, with the sludge gassing and boiling up to the surface of the tank. The light floc-like sludge brought up into the effluent of the first two tanks is carried over into the third tank, where it settles out and is removed twice daily to lagoon-type drying beds. Theoretically it should be possible to carry on this cycle for a long period, but the large volume of sewage received that is not readily digested (such as hair particles, lime grit, etc.) soon destroys the effective settling depth in the tanks and the light floc-like material starts to carry through the third primary settling tank and overflow in the primary effluent.

When the first two settling tanks fill up with sludge and there is little settling space left, provision is made to drain the sludge off into the lagoon-type drying beds. There is no provision for bypassing the settling tanks or any one particular part of the plant, so that raw sewage has to be diverted to the receiving stream without any treatment during the tank cleaning periods. Because the stream is well stocked with fish and because it feeds a large resort lake, every effort must be made to complete the job as quickly as possible, sometimes to the extent of

neglecting some minor repairs that should be taken care of if the tank could be left out of use for two or three days.

Sludge Handling

The 3,400 cu. yd. of sludge removed from the first two tanks averages about 85 per cent moisture. At times it is difficult to move this heavy sludge through the pipe system to the lagoons. Therefore, a 2½ in. fire hose is kept ready at all times during the draining operation to break up any large aggregations of solids that might plug the outlet gate or the drain pipes to the lagoons. An attempt is made to drain the tanks without adding any more water to the sludge than is necessary, because of the drying characteristics of the sludge and the construction of the lagoons.

The lagoons are nothing more than open sludge drying beds with level bottoms and about 3 ft. deep. Each of the 5 beds is between ½ acre and 1 acre in area. When originally built in 1905, provision was made to underdrain the beds, but the underdrains have since been removed; it is doubtful that they will again be installed, because such heavy equipment as caterpillar-type tractor loaders and dump trucks equipped with tire chains work best for sludge removal, but are hard on drain tile with shallow cover.

It has been found that if sludge, regardless of the thickness, is left for a period of 3 or 4 years, it will dry out and take on an earth-like appearance and be quite easily handled when removed from the lagoon type of bed. Because the bed space is needed, enough of the lagoons are cleaned each year, weather permitting, to take care of the always mounting quantity of sludge in the primary tanks, whether the sludge is in suitable handling condition or not.

The primary tanks should be cleaned of sludge every two to three months, but because of the lack of suitable lagoon area it is often necessary to hold the sludge for periods of six months, and the difficulty in handling the sludge multiplies with the time it is retained.

Primary Effluent

The primary tank effluent has a pH of about 10 to 11. This pH value holds until it goes into the receiving stream, indicating that much of the lime coming into the plant passes through the plant in solution, with little of it being removed after it leaves the primary tanks. The raw sludge in the primary tank has a pH of between 8 and 9, with the digested sludge having a pH of 7.6 to 7.8.

Because of the calcium deposition that is always present, plant personnel are extraordinarily conscious of every pipe that might stop up due to this coating on the pipe walls. A couple of years ago, the effluent line from the primary tank to the trickling filter dosing tank became restricted and the flow had apparently reached this condition within a week. An attempt was first made to add chlorine gas to the effluent, then the flow was shut down and the line treated with muriatic acid. Neither treatment, however, gave the hoped-for results of clearing the line. The line was then rodded and it was found that there was a solid stoppage in the pipe which the rods would not move. Cutting a section out of the pipe near the stoppage revealed that two wooden pipe plugs slightly smaller in diameter than the pipe itself had become lodged in the line and were restricting the flow. The plugs were covered with a lime deposit about ½ in. thick, indicating that they had been in the pipe for some time before they had finally turned to a position that cut off the flow.

Trickling Filter

The trickling filter is a trickling filter in name only. The rectangular

bed is fitted with a traveling distributor; crushed field stone is used as the filter media. For the past six years, the filter has been inoperative as a trickling filter, but an attempt has been made to utilize the length of the bed and its rough surface as an aerator.

Experimental data from studies of a pilot trickling filter set up at the plant showed that little reduction in B.O.D. was obtained, and that there was little or no bacteria growth on the stone during the periods when the pH of the primary effluent was as high as 10 or 11. From the experiments it was determined that to get a build-up of growth on the stone it was necessary to eliminate the causes of the high pH. Following the experiment it was noted that a build-up of calcium deposits had formed on the stone during the short time the experimental filter was in operation.

It is believed that a combination of sludge deposits from the primary settling tanks and the calcification of the stone surface has put the filter in its present inoperative condition. Samples of stone from sections of the filter show the media to be one solid mass due to the calcium formations, which are as much as $\frac{3}{8}$ in. thick on the stone surface.

In 1947, when the filter first started to show signs of becoming inoperative, an extension was planned to double the surface area of the filter. Although construction was begun, the project was not completed. As a result, there is now a large tank without filter media at the end of the present filter. This tank volume is being utilized for additional settling space, for the filter effluent. Part of the flow coming into this tank goes to the secondary clarifier, the remainder going directly into the receiving stream.

Secondary Clarifier

In 1937, a secondary settling tank was added. At present it is unable to handle the entire flow, so that some of the filter effluent has to be diverted directly to the receiving stream. Over a period of years the pipe line feeding the clarifier has a lime deposit built up inside the clarifier influent pipe. This build-up in a 12-in. cast-iron line has restricted the flow considerably and presents a difficult problem of cleaning. The line has several bends in it so that it can get beneath the tank and then turn to come up into the riser. Attempts to clean the line with muriatic acid have met with only partial success. Attempts with power sewer rods only served to scrape out that part of the line with which the rods and the tool came in contact. Further efforts are being devoted to the cleaning problem in an effort to find an economical way to clean that line and others in the plant.

High-Water Trouble

The secondary clarifier is only slightly higher than the receiving stream. Following heavy rains or spring thaws the tank is covered with water, backed up through the outfall pipe. This high water gets into the electrical conduits under the catwalks and those buried beneath the pumphouse and the clarifier, and drains out through the fuse boxes and switch boxes in the panel board in the pumphouse. Some trouble has been experienced with wire failures due to insulation breaking down. For safety, therefore, the final clarifier is shut down completely during periods of high water. It is hoped to correct the problem by either rewiring and replacing parts of the old conduit, or by placing new conduit overhead and above the water level.

Receiving Stream

The final effluent going into the receiving stream is generally free of any settleable solids, but the color varies widely. The receiving stream has a good flow for most of the year, but during the late summer months, when

the flow may be quite low, the stream bed and banks build up with long, stringy, grey-colored masses of fungus matter. This condition only exists for about 2,000 to 3,000 ft. below the outfall. Since the receiving stream is stocked annually with fish and the stream flows into a large resort lake, a continuous attempt is made to improve the quality of the effluent with the equipment and facilities available.

Other Problems

During the past six years, the Department has been operating a series of experiments to assist the State Health Department and the consulting engineers to determine what type of treatment facilities can be introduced at the plant to improve the quality of the final effluent and simplify plant operation. The previously mentioned experimental pilot trickling filter was operated for two seasons; an experimental pilot digester was operated for another year. The data obtained were used in preparing plans which are now awaiting further consideration by the Village Board.

The laboratory has been built up over the years, but limited finances have kept it from becoming as complete as is desirable. It is hoped that over a period of years needed equipment will be added to the laboratory and that a better working knowledge of the sewage and the plant operation can be obtained.

Operating problems have not been the only ones. A tremendous public relations problem has grown over the years, as the public has always had the feeling that the sewage treatment plant offered them nothing but took away from them in the way of higher taxes. An attempt has been made to minimize this feeling by continually inviting the public to inspect the plant and letting people know that they will be told the conditions as they actually exist. Each year a group of high school students is taken on a complete inspection trip of the treatment plant facilities. It is hoped by these means to arouse in local taxpayers an awareness of the plant's functions and problems.

The Department has been fortunate in being able to hold together most of its working force. It has been difficult to compete with the wages offered in the surrounding areas, however, as several large industries are engaged in war production and several large government construction projects are under way. Wages for various classifications of help have been raised considerably over the past few years, a factor that has helped to hold the experienced and trained men.

Problems are apparently part of the "game" of operating a sewage treatment plant. If it weren't for those problems many individuals would not find the work so enjoyable and might not be engaged in it. For the author, the past few years have proved very interesting and educational from the standpoint of the work. Also, he has found many associations with others who like himself are too deep in fascinating sewage treatment problems to find life uninteresting.

CHLORINATOR MAINTENANCE AND OPERATION *

By J. P. Kavanaugh

Wallace & Tiernan Co., Inc., Roanoke, Va.

It is with regret that this paper must be prefaced with the statement that there is no magic formula for making a chlorinator take care of itself. It is hoped, however, that by recording and adhering to certain fundamental rules and principles operators will be able to minimize their maintenance and operation problems.

Location of Equipment

Obviously, the first step in proper maintenance of a chlorinator is proper installation—and the first step in proper installation is location of the equipment. If possible, the location should be near the point of application so as to minimize the length of the solution lines. The equipment should be as convenient as possible to the operators and it should be located where there is the least hazard to both employees and equipment. The point of application can be very important and can have some interesting angles. In a number of cases the point of application has been so placed that the chlorinator will be chlorinated; that is, the point of application is in the pipe line ahead of the point where the operating water supply for the chlorinator is taken off. As a result, the chlorinator operating water contains chlorine and prevents formation of organic slime, which these particular supplies produce.

It is fundamental that ease of handling chlorine containers should be considered in selecting a site. The size of the containers to be handled has considerable bearing on this, but in general this discussion is confined to 100- and 150-lb. (net weight) cylinders. The handling of ton containers magnifies the problem considerably and is beyond the scope of this paper.

It might properly be said at this point that chlorine cylinders should not be located below the surface because of ventilating difficulties, chlorine being about 2½ times heavier than air. Rules for handling chlorine are covered later herein.

Equipment Housing

Proper construction and equipping of the chlorinator building can eliminate a number of maintenance problems. There should be ample room for the equipment to be installed, which means that there should be sufficient clearance between walls and other equipment to permit easy access for inspection and maintenance work.

There should be plenty of light for this purpose. It is surprising how many chlorinators have to be worked on with flashlights, and in some cases practically standing on one's head.

Heating is of prime importance. In the winter effort should be made to keep the temperature between 65° and 70° F. Low temperature not only affects operation of the chlorinating equipment, but it discourages proper maintenance from a personal comfort standpoint.

The chlorinator room should be properly ventilated. In certain circumstances natural ventilation will be sufficient. Where large quantities of chlorine are being stored and used and where natural ventilation is a problem or a hazard, forced ventilation should be provided. A chlorinator building located in the open should always contain windows for ventilation as well as lighting, and in addition there should be openings at a low point and

* Presented at 1953 Annual Meeting, Virginia Industrial Wastes and Sewage Works Assn.; Richmond, Va.; May 21–22, 1953.

a high point in the room for continuous ventilation. In remotely located buildings it is generally necessary to cover windows with substantial shutters to protect them from boys with rocks and air rifles.

The chlorinator room should be as dry as possible. Heat and ventilation have a large part in this, but proper drainage is also a contributing factor. Maintenance of water piping cannot be overlooked.

All of these things—ample room, proper heating and ventilation, and adequate light—are conducive to cleanliness, and the author has never seen a clean piece of equipment that was in poor condition mechanically. A plant's chlorinator installation is valuable and should be protected.

General Conditions for Maintenance

If a plant is fortunate enough to have duplicate chlorinators the maintenance problem is eased considerably by reason of not having to wait until a little problem gets big, and in not having to do a hasty job of repair. Whether or not duplicate chlorinators are provided it is assumed that the good operator will become as familiar as possible with the equipment. A study of the equipment should begin when it is installed and when there is a representative of the manufacturer present. This study can continue, if necessary, with subsequent visits of the manufacturer's representative. Instruction books furnished with equipment contain a great deal of both general and specific information, but in spite of this problems sometimes arise that are not in the book.

With proper knowledge of the equipment, regular and adequate inspection is a "stitch in time." At these regular inspections it should be determined that the equipment is performing its functional duty—that is, that it is feeding the desired amount of chlorine and that there is no evidence of trouble to come. The latter condition may be determined by liquid levels, gage readings, or in other ways peculiar to the particular unit.

One of the more important duties of an inspection is to check for leaks. Any leak is highly important and should be corrected at once. The most effective way to locate leaks is to use an ammonia-saturated cloth on a stick or wire. It may not be possible to get within a foot of a leak was just an open bottle of ammonia. Moreover, it is surprising how many chlorinator installations do not have a bottle of ammonia available or where the ammonia has lost all of its strength due to being left open. Some operators may take this regular inspection schedule lightly, but there are others who will not. Those who will not are the ones who have experienced a false sense of security because observations over a long period did not disclose any difficulty, then have finally had a sad experience because of their complacency. Neither must one be like the operator who was instructed to inspect the chlorinator and make an ortho-tolidine test three times a day and record the results on a chart. The superintendent visited the installation the next day to see how the operator was carrying out his new instructions and found that he was doing it to the letter—he had inspected and tested at 8:05, 8:10, and 8:15.

Operating Suggestions

When it comes to actually working on a chlorinator, certain equipment should be available and certain rules should be followed. In the first place, there should be a supply of spare parts and a supply of gaskets. The spare parts should certainly include glassware.

Working on a chlorinator generally involves disconnecting gasketed joints. The old gaskets, particularly if of fiber or lead, should almost invariably be discarded. Occasionally a soft rubber gasket that has been in use only a short time may be used again if neces-

sary. After the old gasket has been removed the gasket joint should be cleaned. Normally it is necessary to use one gasket at a joint. Frequently two or more gaskets are found at one joint, which is certainly poor practice, and which certainly multiplies the possibility of leaks.

Disconnecting joints, and of course leaks, involve the escape of some chlorine. In one plant provision has been made for working around a leak in comparative comfort, and preventing gas from the leak from spreading over the room, by using a suction funnel attached by hose to a water ejector similar to the injector on a chlorinator. The end of the funnel is placed near the leak and the gas sucked into it is disposed of with the water operating the ejector. The new Richmond, Va., water filtration plant has a similar arrangement for disposing of the dust from carbon and other chemicals.

One should be particular about cleaning fluids used on the internal parts of a chlorinator. One of the best all-around cleaning fluids is carbon tetrachloride. Wood alcohol also is acceptable, as neither of these fluids react unfavorably with chlorine. Neither grain alcohol nor denatured alcohol should be used, however, and some of the commercial cleaning fluids react particularly badly with chlorine to form waxes and other objectionable solid matter. Carbon tetrachloride is marketed commercially as a cleaning fluid under several brand names. The fluid used in certain types of fire extinguishers also is carbon tetrachloride. The cheapest way to buy carbon tetrachloride, however, is as such in drug stores, where it is sold by the pound. In cases of necessity hot water may be used, but it is imperative that the tube or part being cleaned be thoroughly dried before re-use.

Moist chlorine is particularly destructive, which makes it advisable to keep both the internal and the external parts of a chlorinator dry. This is also true of the metals of any other equipment which may be in a room where there is likely to be chlorine.

To protect external parts it has long been a practice to apply grease. The object of this, of course, is to insulate the metal from moisture, particularly moisture that has picked up chlorine. Daubing of grease all over the chlorinator seems to be just the lesser of two evils, as there seems to be natural aversion to doing the necessary work on a chlorinator that is covered with grease. If grease is to be used it is better to rub it on lightly with a rag and remove it often with a clean rag to eliminate the moisture that has collected. This procedure maintains the good appearance and returns to the premise of clean equipment normally being in good mechanical condition.

An excellent protective coating for plated parts is clear lacquer. It is probably a lot less trouble in the long run than greasing and, if anything, is more effective for the purpose. Of course, for joints that are disconnected often, such as on auxiliary tank valves, maintaining a continuously lacquered coating could be somewhat of a chore. Recently there has appeared on the market clear plastic lacquer in pressure spray cans. An effective job of reaching inaccessible places and of doing a complete lacquering job with ease can be accomplished by this method.

Lubricants for hard rubber and metal threads should be used with caution. No lubricant should be allowed to remain where chlorine is normally present. This brings up a note of caution regarding iron pipe headers for chlorine gas. Pipe fitters frequently use oil in threading the pipes; therefore, the inside of the pipes should be swabbed clean before assembling.

It should be re-emphasized that a supply of strong ammonia should be on hand, with the bottle kept stoppered and preferably in a cool place. It is not advisable to place it in the

tray water of a vacuum chlorinator to keep it cool. It is also not advisable to let ammonia get too hot. Pressure builds up in the bottle and if it doesn't blow out the stopper, it may blow out in someone's face when the stopper is removed. This has happened and can be serious. Household ammonia is strong enough for leak testing, but aromatic spirits of ammonia is of practically no value.

Handling Chlorine

Certain things should be known about chlorine by those who are to handle it. The most common sizes of containers in use are 100-, 150-, and 2,000-lb. cylinders. The content of these cylinders is liquefied chlorine gas. Fortunately the gas liquefies at comparatively low pressures, which simplifies handling large quantities of the gas in condensed form. In hot weather the pressure on the inside wall of a cylinder may be as high as 125 lb. per sq. in. or more. Pressure on a new cylinder is sometimes higher than normal due to the presence of inert gases, which are soon drawn off with the first chlorine used. In cold weather the pressure in a container may go as low as 40 or 50 lb. per sq. in. The temperature-pressure curve contained in all chlorinator instruction books is useful for interpreting this relationship between temperatures and pressures.

The pressure in the container keeps the chlorine in liquid form. As received from the chlorine supplier, containers are a little more than three-fourths full of liquid. This is to allow for expansion of the liquid with higher temperatures. When the container valve is opened the pressure is relieved and some of the liquid passes into the gaseous form. It is in this form that it is controlled and measured in the chlorinator.

The change from a liquid to a gas requires heat, which is obtained from the surrounding air. The absorption of heat has a cooling effect on the cylinder, thereby reducing the pressure. Therefore, if gas is drawn off too rapidly freezing may occur, which in turn will retard the flow of gas. It can be seen that proper circulation of air around the cylinders is important so that the cooled air can be replaced by warmer air.

The rate of withdrawal from a 100- or 150-lb. cylinder at normal room temperature is about 40 lb. per day, although this rate may be doubled for short periods. If more than 40 lb. per day is required, a number of cylinders may be hooked up to a common manifold. A note of caution is in order here. If cylinders under high pressure are connected by a manifold with cylinders under low pressure, liquid may pass from the high-pressure to the low-pressure cylinders. This could be serious if the low-pressure cylinders cannot accommodate the additional liquid.

A fairly common occurrence is the reliquefying of chlorine when passing from a high-temperature to a low-temperature area. This may occur when a new cylinder has been stored in some place warmer than the chlorine room, or it may occur when cylinders in use are placed near a source of heat, such as a radiator or other heating units. The control apparatus should always be nearer to the source of heat than the container. In many cases containers are placed in rooms which are cooler than the chlorinator room and this chlorine piped to the chlorinator.

All chlorine containers have a fusible plug designed to melt at about 160° F. to relieve dangerous hydrostatic pressure resulting from high temperatures. These plugs certainly never should be tampered with and the temperature of the chlorine room should never be higher than necessary for good operation. Artificial heating of containers or piping to increase the gassing rate can be extremely dangerous.

Sometimes, for purposes of conveni-

ence, chlorine is handled as a liquid from the container to the chlorinator. It is then necessary to evaporate the chlorine at the chlorinator end of the line. This method of handling is so infrequently used, however, that it should be performed only under the guidance of trained personnel in strict accordance with established procedures.

The following simple set of rules has been devised for handling all types of chlorine containers:

1. A container holding chlorine should be handled with care.
2. The valve bonnet should not have to support the full weight of the container, such as in hoisting and lifting.
3. Do not drop containers or permit them to strike each other violently.
4. Be sure that the container valve is closed before removing the valve protective cap.
5. When returning empty containers, close the valve and test for leaks. Be sure that the valve protective cap and the bonnet are in place. The cap should be kept with the container during use. It is illegal to ship a defective or leaking container.
6. Open the container valve slowly. Use only wrenches supplied by the manufacturer. Cylinder valve wrenches are 3½ in. long, and they are that length for a reason.
7. The thread on the outlet of a cylinder valve is not a standard thread. Do not try to use a standard thread fitting on it.
8. Store containers where it is dry and preferably cool. Do not store where there is a fire hazard.
9. Weighing is the only means of determining how much chlorine is in a cylinder. Scales having a platform flush with the floor are preferable.
10. Operate chlorine valves once a day to keep this stem free.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Biennial Report of the Hartford (Conn.) Metropolitan District Sewage Treatment Plant for the Years 1951 and 1952 *

By George E. Cramer, *Operations Engineer*

The plant is operated only when the Connecticut River is at or below elevation 8.0 (city datum), at which stage river discharge is estimated at 20,000 c.f.s. At higher stages gravity flow to and through the plant could not be obtained and the dilution obtained makes treatment unnecessary. During the periods of shutdown, when insufficient gas is being produced to supply heating needs, auxiliary oil fuel is used in the boilers, which have combination type (oil and gas) burners.

Since 1947 digester operation had become increasingly unsatisfactory due to declining heat transfer efficiency and inert sludge build-up. The condition became critical in late 1951 and early 1952. To correct it, all four digesters were dewatered and cleaned and the heating coils were descaled in the spring of 1952. Heat transfer returned to normal and digester operation has been satisfactory since.

Removal of the wool filter cloths was necessary after 400 working hours apiece. Although the cloths were not deteriorated and were still serviceable, ferric chloride used had increased be-

* For last previous extract see This Journal, **24**, 3, 329 (Mar., 1952).

yond the economic limit. This was in spite of thorough and regular washing with a dilute solution of muriatic acid or trisodium phosphate. Use of a steam cleaning device on the cloth, as well as on the wire mesh drum, has done much to improve the operation of the filters.

Table I is a summary of the plant operation data for 1951 and 1952.

TABLE I.—Summary of 1951 and 1952 Operating Data at Hartford, Conn.

Item	1951 Average	1952 Average
Estimated population served	230,000	230,000
Rainfall (in.)	43.21	38.92
Sewage flow (m.g.d.)*	31.7	34.6
Operating time (% of year)*	66.6	60.7
Number of employees	25	25
Screenings (cu. ft./m.g.)	1.7	1.6
Grit (cu. ft./m.g.)	1.6	1.6
Raw sludge removed:		
Total (m.g.)	10.83	11.33
Moisture (%)	93.5	93.8
Dry solids (lb./day)	24,820	26,830
Dry solids (lb./m.g.)	769	678
Volatile solids (%)	69.5	71.2
Detention in tanks (hr.)	2.75	2.35
Ether soluble grease (%)	26.1	24.9
Digestion tank data:		
Temperature (° F.)	97.0	98.0
pH	6.9	6.9
Hot water, in (° F.)	142	128
Hot water, out (° F.)	134	119
Total sludge removed (m.g.)	6.27	5.96
Moisture of sludge removed (%)	95.3	95.0
Volatile solids (%)	48.5	50.5
Ether soluble grease (%)	13.4	10.4
Sludge gas data:		
Gas produced, total (10^6 cu. ft.)	40.84	43.49
Gas used, total (10^6 cu. ft.)	16.85	17.07
Production per capita per day of operation (cu. ft.)	0.74	0.84
Carbon dioxide content (%)	34.0	34.0
Net heating value (B.t.u.)	570	570
Elutriated sludge data:		
Total sludge from elutriation tanks (m.g.)	5.52	5.49
Moisture (%)	94.7	94.7
Total dry solids (10^6 lb.)	2.55	2.35
Volatile solids (%)	46.8	46.3
Vacuum filter operation data:		
Total operation (days)	95	90
Total operation (hr.)	1,109.8	1,085.4
Total $FeCl_3$ used (lb.)	51,076	47,566
$FeCl_3$, dry basis (%)	2.01	2.02
Total sludge cake produced (10^6 lb.)	7.53	6.83
Cake moisture (%)	66.3	65.0
Rate (lb./sq. ft./hr.)	6.50	6.06
Total dry solids in cake (10^6 lb.)	2.55	2.35
pH of filtrate	6.2	6.4
Sludge cake produced, total (cu. yd.)	4,428	4,018
Operating cost data ($):		
Total	118,613.03	134,904.97
Per m.g. treated	15.67	17.72
Per capita per year	0.52	0.59
Analytical data:		
Suspended solids:		
Influent (p.p.m.)	174	172
Effluent (p.p.m.)	67	67
Reduction (%)	60.0	60.2

TABLE I.—Summary of 1951 and 1952 Operating Data at Hartford, Conn.—*Continued*

Item	1951 Average	1952 Average
Raw sludge:		
Moisture (%)	93.5	93.8
Volatile solids (%)	69.5	71.2
Digested sludge:		
Moisture (%)	95.4	95.0
Volatile solids (%)	48.5	50.5
Elutriated sludge:		
Moisture (%)	94.7	94.7
Volatile solids (%)	46.8	46.3
Reduction in volatile matter by digestion (%)	60.6	58.4
Grease (%):		
Raw sludge	26.1	24.9
Digested sludge	13.2	10.4
Digestion and filtration alkalinities (p.p.m. as $CaCO_3$):		
Digested sludge	2,734	2,751
Elutriated sludge	280	271
Elutriate	857	858

* Plant closed during all or part of certain months; river elevation above operating level.

Annual Report of the Greater Winnipeg (Man.) Sanitary District for the Year 1952 *

By N. S. Bubbis, *General Manager*

In addition to normal operating and maintenance work, the District during 1952 replaced the Hart Avenue river crossing, damaged in the 1950 flood, with steel pipe; continued test operation of the experimental sludge la-

* For last previous extract see This Journal, **24**, 7, 915 (July, 1952).

TABLE II.—Summary of 1952 Operating Data, Greater Winnipeg Sanitary District *

Item	Average
Equivalent population, estimated	318,200
Rainfall (in.)	14.26
Sewage flow (m.g.d.)	25.5
Grit (cu. ft./m.g.)	1.5
Settleable solids:	
Plant influent (ml./l.)†	6.7
Clarifier effluent (ml./l.)	2.3
Removal (%)	65.3
Suspended solids:	
Plant influent (p.p.m.)†	304
Clarifier effluent (p.p.m.)	139
Removal (%)	54.4
B.O.D., 5-day:	
Plant influent (p.p.m.)†	254
Clarifier effluent (p.p.m.)	136
Removal (%)	46.6
Raw sludge to digesters, total (m.g.)	13.33
Dry solids (tons/day)	12.8
Solids (%)	9.2
Volatile (%)	67.6
Sludge from digesters to filters, total (m.g.)	7.16
Digested sludge:	
Solids (%)	7.6
Volatile (%)	48.2
pH	7.3
Sludge gas:	
Produced, total (mil. cu. ft.)	65.10
Used for heating, total (mil. cu. ft.)	25.87
Wasted, total (mil. cu. ft.)	39.23
Produced, daily (cu. ft.)	178,350
Wasted, daily (cu. ft.)	112,566
CO_2 (%)	32.2
O_2 (%)	0.2
CH_4 (%)	67.1
Elutriated sludge:	
Sludge handled, total (m.g.)	7.16
Dry solids, effluent (%)	0.38 to 0.76
Alkalinity (p.p.m.)	1,060 to 1,300
pH	7.15
Solids (%)	7.6 to 11.3
Volatile (%)	40.2 to 56.1
Sludge cake from plant:	
Total, wet (tons)	1,948.5
Total, dry (tons)	541.1
Ferric chloride used:	
Total (lb.)	48,018
Dose (% of solids filt.)	4.0 to 5.4
Days filters operated	44
Filter rate (lb. dry sol./sq. ft./hr.)	3.9 to 5.0
Cost of operation ($):	
Collection	80,581.37
Treatment	162,562.19
Total	243,143.56

* All flows and capacities in U. S. gallons.

† Includes solids in elutriate and filtrate returns.

goons and sand beds (reported elsewhere in THIS CORNER); continued the District's campaign on control of industrial wastes from packing and slaughter houses by cooperating in planning and operation of pretreatment; completed installation of the Montcalm screening and pumping station; completed enlargement of the Colony Street pumping station; and assumed maintenance and operation functions on flood pumping stations in the District.

A summary of 1952 operating data is given in Table II.

Annual Report of the District of Columbia Sewage Treatment Plant for the Fiscal Year 1952 *

BY RALPH E. FUHRMAN, *Superintendent*

The average daily flow of 172.7 m.g.d. represented an increase of 8 per cent over the previous year. Construction of four settling tanks, four digesters, and additional gas storage facilities was completed and the units were placed in service. Also, design of the sludge disposal plant (building and equipment) was substantially completed. A contract was let for chlorination equipment and plans for specifications for the chlorination building were completed. Preliminary design for secondary treatment by the high-rate activated sludge process was in progress, after pilot-plant experiments with modified aeration.

Equivalent Population Factor

In former years, population equivalents have been calculated on the basis of 0.20 lb. of B.O.D. per capita per day. The widespread use of synthetic detergents in place of soap has tended to lower the population equivalent values, as syndets have much lower B.O.D.'s than soaps. The present per capita B.O.D. value appears to be 0.18 lb. per day. On this basis, the equivalent population is 952,000.

* For last previous extract see THIS JOURNAL, **24**, 9, 1179 (Sept., 1952).

TABLE III.—Distribution of Operation and Maintenance Costs

Function	Personal Services	Materials and Supplies	Electrical Energy	Shipping Costs	Miscellaneous	Total
Administration	$ 26,562	$ 667	—	—	$ 1,077	$ 28,306
Laboratory	20,308	407	—	—	1,076	21,791
Sewage pumping	32,618	275	$49,069	—	2,154	84,116
Grit removal	19,859	316	378	—	2,154	22,707
Grit disposal	1,336	—	—	—	—	1,336
Grease separation	—	—	2,699	—	2,154	4,853
Sedimentation	29,879	3,450	2,517	—	2,154	38,000
Sludge digestion	16,424	477	574	—	2,154	19,629
Sludge elutriation	3,049	175	151	—	2,154	5,529
Sludge dewatering	29,025	21,273	2,258	—	2,154	54,710
Sludge cake disposal	—	—	—	$6,118	—	6,118
Shops	10,189	663	—	—	—	10,852
Roads, walks, and grounds	17,088	220	—	—	—	17,308
Sub-total	$206,337	$27,923	$57,646	$6,118	$17,231	$315,255
Inventory changes	—	—	—	—	—	6,460
Total budgetary expend. for oper. and maint.						$321,715

Operating Costs

Operating costs of the plant have been charged and distributed to actual sewage treatment functions (Table III). The cost of electrical energy has been deduced on the assumption that 85 per cent of the power plant operating costs are chargeable to electric energy production, the remaining 15 per cent being charged to plant heating. The accounts which are general in their service to the entire plant (such as plant lighting, garage, storeroom, lawns, roads, walks, and miscellaneous) have been charged to the tabulated functions equally, counting the administration and laboratory functions as a single unit, since they occupy a single building.

In addition to the budgetary expense of $321,715, as shown in Table III, there are other costs of plant operation included in other sections of the District of Columbia appropriations. For example, water supplied by the D. C. Water Division is not paid for directly by the plant. At an estimated cost of $60 per m.g., the metered consumption of 61.1 m.g. was valued at $3,670.

Also, sludge cake shipped to the D. C. Department of Correction is applied to the soil, but no allowance is made for the fertilizing value replacing commercial fertilizer. Therefore, the costs of disposing of the sludge are properly chargeable against the sewage treatment operation. In 1951–52 this operation expenditure amounted to $7,945.

Including these costs, the operational charges for pumping and treating 63,207 m.g. of sewage by primary treatment were $5.27 per m.g. Of this, pumping costs amounted to $1.33 per

TABLE IV.—Summary of Operating Data for Fiscal Year 1952, District of Columbia Sewage Treatment Plant

Item	Average
Sewage flow (m.g.d.)	172.7
Equiv. pop.	952,000
Night soil handled at plant:	
Loads, total	208
Gallons, total	99,860
Grit removed (cu. ft./m.g.)	2.5
Solids (%)	74.7
Volatile (%)	11.5
Suspended solids:	
Raw sewage (p.p.m.)	170
Effluent (p.p.m.)	80
Reduction (%)	52.9
5-day B.O.D.:	
Raw sewage (p.p.m.)	120
Effluent (p.p.m.)	84
Reduction (%)	30.0
Raw sludge:	
Removed (lb., dry/day)	130,288
Solids (%)	6.7
Vol. sol. (%)	65.9
Grease	19.8
Scum:	
Removed (g.p.d.)	10,728
Solids (%)	18.4
Volatile (%)	92.2
Sludge digestion:	
Vol. sol. added daily (lb., dry)	89,699
Dig. sl. removed (g.p.d.)	90,000
pH dig. sludge	7.3
Temp. dig. sludge (°F.)	92
Grease in dig. sl. sol. (%)	8.3
Susp. sol. in sup. (p.p.m.)	25,643
Sludge gas:	
Total prod. (cu. ft./day)	689,000
Used (cu. ft./day)	434,000
Wasted (cu. ft./day)	255,000
Produced (cu. ft./cap./day)	0.8
B.t.u., gross (per cu. ft.)	641.0
B.t.u., net (per cu. ft.)	589.4
Methane (%)	60.8
Carbon dioxide (%)	34.5
Elutriated sludge:	
Solids (%)	8.0
Vol. sol. (%)	46.4
Ratio wash water to sl. vol.	1.4
Alk., dig. sl. (p.p.m.)	2,713
Alk., elut. sl. (p.p.m.)	635
Eff. wash water ratio	3.3
Elutriate:	
Susp. sol. (p.p.m.)	3,467
Alkalinity (p.p.m.)	1,418
5-day B.O.D. (p.p.m.)	902
Sludge dewatering:	
Dewatering time, total (days)	208
Filter hours, total	3,332.1
Cake produced, total (tons, wet)	19,769.0
Solids in cake (%)	28.3
Dry solids in cake, total (tons)	5,592.4
Yield of solids (lb., dry/sq. ft./hr.)	6.7
$FeCl_3$ (%)	4.18
Susp. sol. in filtrate (p.p.m.)	209
Operation and maintenance cost, total	321,715

m.g. and sludge shipping and cake disposal costs amounted to $0.22 per m.g. ($0.71 per ton of vacuum filter cake produced). The marked reduction in the latter figures from $0.52 per m.g. and $1.22 per ton of previous fiscal year results from the approximately 6,000-ton decrease in rail shipments.

Operating data for the fiscal year 1952 are summarized in Table IV.

SLUDGE DRYING TESTS AT WINNIPEG *

By N. S. Bubbis

General Manager, Greater Winnipeg Sanitary District, Winnipeg, Man.

To determine the method of sludge handling to be adopted when plant extensions now under way are completed, sand beds and lagoons have been under test at the Winnipeg, Man., sewage treatment plant since January 1951. Results of the first two years of testing, although not conclusive, may be of interest to others concerned with the sludge drying problems.

The plant handles the sewage from Winnipeg and five smaller communities, with a total population of 315,240. The 39,461-ft. intercepting sewer varies from 42 in. to 90 in. in diameter and is made of alkali-resisting cement concrete. The dry-weather flow of 26 trunk sewers is delivered to 16 comminutor stations, where it is reduced to ¼-in. size before discharge to the interceptor. At the plant sludge is pumped to four digesters, the gas produced being used for heating the digesters and buildings, or burned as waste. Digested sludge currently is elutriated and vacuum filtered. In 1952 a total of 541.1 tons of filter cake was produced.

Test Conditions

Each of the six test lagoons is 100 by 150 ft. in size. Three of them also are provided with tile underdrains—an unusual feature, as lagoons normally are not underdrained. However, the highly impermeable underlying clay (Red River gumbo) indicated that such an arrangement might be desirable. The two drying beds are each 50 by 150 ft., providing a total of ⅛ acre of drying area.

The year 1952 was the third warmest on record, with a mean temperature of 39.1° F. It also was the second driest on record, the total precipitation being 14.26 in., or 70 per cent of normal. The mean relative humidity of 74 per cent was slightly lower than the 14-yr. average of 78 per cent.

Digested sludge and elutriated digested sludge were tested in both the underdrained and plain lagoons (Table I) and on the sand beds. Shrinkage of the sludge by drying out is indicated by the reduction in depth or volume at various times. After the ground and sludge had thawed out it was found that the top and bottom layers in lagoon No. 4 were drier than the center (Table II). The sludge in the underdrained lagoon was dry enough to be removed after 18 months, whereas the sludge in the plain lagoon could not be removed then and probably would require at least 24 months.

Frost is an important factor in operation of lagoons in this area. As a result of frost, no drying takes place from November to April and no water percolates through the underlying strata. The small evaporation from the frozen sludge can be explained by the insulating value of the ¼- to ½-in. deep layer of dry powdered sludge par-

* Adapted from 1952 Annual Report of the Greater Winnipeg Sanitary District.

TABLE I.—Types and Amounts of Sludge Put in Test Lagoons

Lagoon		Sludge						
No.	Drains	Type	Quan. (gal.)[1]	Dry Sol. (lb.)	Water (%)	Depth (ft.)	Vol., 12/31/52	
							(gal.)[1]	(cu. yd.)
2	Yes	Dig., elut.	671,200	480,600	91.8	4.1	240,000	1,120
3	Yes	Dig.	748,336	497,000	92.3	4.0	230,000	1,070
4	Yes	Dig.	337,336	154,000	94.6	3.75	210,000[2]	980[2]
5	No	Dig.	618,000	428,000	91.9	2.9	155,000	1,020
6	No	Dig.	565,184	317,300	93.5	3.9	220,000	1,020
7	No	Dig., elut.	725,800	527,000	91.6	4.65	300,000	1,400

[1] U. S. gallons.
[2] 450 cu. yd. dry sludge removed Nov. 8–20, 1952; refilled.

ticles left on the surface. Actually, winter evaporation of the sludge moisture amounts to less than 0.1 ft. No obnoxious odors have been encountered from the sludge lagoons.

Surface Drainage Important

Although tests showed that the underdrained lagoons would remove the water more quickly than the plain ones, it soon became apparent that removal of the surface water was the most important factor in sludge dewatering. Natural evaporation was too slow, so it was decided to decant the water from the lagoons. The first method tried was to place piles of coarse stone over the underdrains at the end of the lagoons. Sludge piled up against the stone, however, and quickly stopped water percolation. Wooden drain boxes with weir stop-planks were then constructed at the lagoon bank opposite the sludge inlet pipe. This allowed the surface water to be drawn off slowly and discharged to a sewer.

TABLE II.—Water Content of Sludge in Lagoon No. 4

Date (1952)	Total Depth (ft.)	Water Content (%)			
		Top Inch	1-Ft. Depth	2-Ft. Depth	Bottom
June 10	2.7	48.5	62.1	69.5	72.5[1]
June 17	2.4	29.5	57.0	62.6	65.3
July 24	2.3	31.6	54.5	46.3	—
Aug. 13	—	—[2]	—[2]	—[2]	—[2]
Oct. 10	—	—[3]	—[3]	—[3]	—[3]

[1] Traces of frost.
[2] Composite sample.
[3] 1 cu. ft. dried sludge weighed 39.5 lb.

Conclusions

Tentative conclusions resulting from the tests are as follows:

1. Sand beds will give four loadings per year, but can be used only during the summer season. The high construction cost and the large area required prohibit their use at Winnipeg.
2. Obnoxious odors are not expected from the lagoons.
3. Without drainage of surface water, sludge in the underdrained lagoons could be removed in 18 months, but in lagoons without underdrains would require at least 24 months.
4. Other factors make underdrains unjustifiable and successful operation of lagoons will depend on the ability to decant or otherwise remove all excess liquids from the lagoons.
5. Although sludge lines frozen during the severe winter months could be thawed out, consideration might be given to providing space for sludge storage so that large amounts of sludge could be discharged to the lagoons at greater intervals.

TIPS AND QUIPS

Public Relations on the Air

An extremely interesting 15-min. program on the Little Rock (Ark.) Sanitary Sewer System and its operation and maintenance recently was broadcast over radio station KVLC of that city. Participating were the mayor and the chairman of the Sewer Committee, as well as C. M. Greene, R. Ouellette, and T. W. Clapham, respectively inspector, general foreman, and manager. Putting the program on the air at 6:00 PM on a Sunday evening insured a maximum opportunity for reaching the greatest number of listeners.

Following introduction of the participants and some general data concerning the Sewer Committee and how it is appointed, the program followed the question-and-answer technique. Subjects discussed included the function of the Sewer Department, use of the funds raised by the sewage service charge, bonded indebtedness of the system, installation of sewers, inspection of connections, and operation and maintenance of the system. To any interested person the program presented a concise but over-all picture of the system's functions and problems. It also offered an excellent opportunity to point out how the general public can be helpful in reducing the problems, and therefore the costs, by a little care in its use of the sewers.

A progressive administrator is always seeking to improve public relations for his organization, especially through informative talks to the people served. What an excellent medium the local radio station makes!

Plastic Cover-All

Claimed to be rugged, durable, and 100 per cent waterproof, a vinyl plastic foul-weather cover-all now on the market also is oil and grease resistant. Moreover, it is odorless, flame-proof, and will not stick. The cover-all is marketed under the name of "Weth-A-Dri" by Car-Blair Ltd., 40 West 57th St., New York 19, N. Y.

Sludge as Cover for Ash Dump

Experiments on covering the power station ash dumps with digested sludge were reported in a paper on "Operation of the Coleshill Works of the Birmingham Tame and Rea District Drainage Board, 1938–1952," presented at a meeting of the Midland Branch, Institute of Sewage Purification, at Birmingham, England, on April 16, 1953.

In answering questions raised during the discussion the author, C. E. Winsor, made the following points:

1. Use of digested sludge as a top dressing on powerhouse ash dumps (in layers up to 12 in. thick) prevented nuisance from blowing ash dust.
2. Addition of a commercial fertilizer to the sludge surface gave very good yields of grass from mixed seed.
3. Clover, contained in the mixed seed, was suppressed by the luxuriant growth of all grasses.
4. The industrial sludge from the neighboring Minworth sewage treatment plant required a top dressing of soil on the sludge before grass seeds would germinate.
5. Disposal of digested sludge on sanitary fills and ash dumps offers a means of reclaiming otherwise waste areas.
6. The amount of sludge required on the ash dumps was relatively small in quantity and intermittent in demand. This use, therefore, would not solve any of the sludge drying and disposal problems at the Coleshill plant.

Fire Retardant Paint

A new washable, flat, oil base, fire retardant paint may well prove to be

one of the greatest advancements yet made in preventing the tremendous loss of life and property that can result from rapidly spreading flame. Easily applied to the interior of buildings by brush or spray, the new paint is claimed to contain its own "built-in" fire extinguishers; when exposed to flame it pours out carbon dioxide and calcium chloride, which smother fire and retard the spread of flame right on the surface. The paint is made in white and six colors by the Fyr-Kote Co., 27th and Douglas Streets, Omaha, Nebr.

Safety Incentive

In a recent letter, W. A. Ryan, consulting chemist of Rochester, N. Y., not only called attention to the reduced status of superintendents, operators, and laborers in village sewage treatment plants, but also to the personnel turnover resulting therefrom. "This turnover," says Mr. Ryan, "presents a greater need than ever to teach the new men safety precautions." He also suggests that every plant should have a large sign on its bulletin board outlining, in large type, all the pertinent safety rules and precautions.

To make the men even more safety conscious, Mr. Ryan suggests that those with good safety records should be allowed an extra day's vacation with pay every six months.

Operator Training Need

To determine the need for training of sewage treatment plant operators in Michigan, and the level of training most needed, a cooperative survey was made by the Educational Committee of the Michigan Sewage and Industrial Wastes Association and the Michigan State Health Department. The survey results, reported at the 1953 annual meeting of the association, indicate a hitherto unsuspected high turnover in plant personnel, with an equally critical need for short course and other training at all levels.

According to the committee report, during 1951 and 1952 there were 70 changes of supervisory personnel in the 160 plants in the state. It must be recognized, of course, that some of these changes may be duplications. As a result of the high turnover in that phase of plant operation, however, a plant personnel study revealed that 79 individuals needed basic instruction, 88 required instruction above the elementary level, and 41 required top-level instruction.

Garbage Bonanza?

Latest in the long line of attempts to wring money out of garbage is reported to be an offer of one concern to share its profits with colleges endorsing its garbage processing system for installation in the college communities. The system is said to utilize "selected" thermophilic bacteria to reduce raw garbage to salable compost in 48 hr.

The necessary equipment seemingly also includes rose-colored glasses—the promoter is said to be offering as much as 75 per cent of the profits of any local installation to each college endorsing the system. Returns to a college situated in a city of 20,000 have been estimated at $12,000 per year.

A short while ago it was "golden" garbage; but it would appear that someone's now trying to process it by high finance.

Reviews and Abstracts*

Disinfection of Wastes by Chlorination. By H. Heukelekian, R. Day, and R. Manganelli. *Ind. Eng. Chem.*, **45**, 1004 (1953).

The starch-iodide, o-tolidine, and amperometric procedures were used to determine chlorine residual in a study of bacterial survival in a variety of industrial wastes after chlorination. There was no consistent difference or superiority in the chlorine residual procedures as correlated with bacterial kill. Each residual technique had some weakness, although the amperometric titration procedure gave the least trouble. R. S. Ingols

Determination of Milligram and Submilligram Quantities of Copper. By K. Tantranon and B. B. Cunningham. *Anal. Chem.*, **25**, 194 (1953).

The method uses the iodate titration of cuprous thiocyanate in very minute volumes for microgram amounts of copper.
R. S. Ingols

Industrial Water Pollution Abatement. By Roy F. Weston. *Chem. Eng. News*, **31**, 2, 134 (1953).

Misuse of water as a carrier of waste has led to the development of public policy relative to water pollution control. Excerpts from New York and Pennsylvania laws show typical legislation.

Because development of industry is dependent on proper use of water resources, industries have adopted policies relative to pollution abatement, to the prevention of future pollution, to the expenditure of funds for these purposes, and to cooperation with regulatory agencies. The latter are usually sympathetic and helpful where an industry shows good faith.

Water pollution abatement is a public relations problem. The public, rather than the industry, usually benefits by expensive water pollution control.

Pollution control is a technical problem requiring specialized industrial departments or the use of consultants. The two usual problems are correction of existing conditions and maintaining future approved quality.

A plant waste disposal survey is an important factor in these problems. Consideration should be given to effluent treatment only when all other means of waste control have been fully exploited. Every plant has its own problem. Following completion of an approved waste disposal unit, competent operation and control of it is necessary to maintain the company policy. R. E. Anderson

Abwasserreinigung im Emschergebiet (Sewage Treatment in the Emscher District). By G. Müller-Neuhaus. Reprint from *Chem. Ind.* (German), **3**, 1 (Jan., 1951).

This article describes the development of waste treatment measures made necessary by the extensive industrial expansion during the past 75 years in the Rhein-Westfall region of Germany. A special law (1904) created an Emscher Valley Sanitary District, a self-governing body which regulates the drainage and waste treatment, and constructs, maintains, and operates the treatment works in the Emscher region. Membership of municipal and industrial representatives in the association and responsibility for funds to carry out the association work are dependent upon the relative amounts of waste discharged. Governmental control is exercised through the Ministry of Economics and Commerce of the North Rhein-Westfall state.

The District started activity with the construction of Imhoff-Emscher tanks to take care of municipal sewage. By 1920, 23 plants with a total of 138 Imhoff tanks were treating the waste of 1,100,000 persons, or 52 per cent of the population of

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

the region. The District met the challenge of increasing industrial wastes with study and experimentation and established the policy of recovery of valuable materials and the treatment of wastes, so far as possible, near the source. Recovery of phenols as a result of industry-district cooperative effort is especially significant. By 1950 the District had cleaned up 81.5 km. of Emscher River channel and 261 km. of secondary brook channel, and had 51 pumping stations (17, 462 hp.), 22 primary plants treating 1,500,000 cu. m. per day (396.3 m.g.d.), and 13 plants recovering a total of 300 tons of phenol per month. The value of the complete works is about 240,000,000 D.M. ($56,750,000).

Of the 27,900,000 D.M. budgeted in 1950, 5,100,000 D.M. were for management, operation, maintenance, and financing; 14,200,000 D.M. were for elimination of damage to existing plants due to mine settling; and 8,600,000 D.M. were for special projects, including elimination of World War II damage. Of the funds received in 1950, 90 per cent came from the mining industry, 2.6 per cent from iron and steel works, 2.2 per cent from other industries, and 5.2 per cent from municipalities. G. R. GRANTHAM

Semimicrodetermination of Dissolved Oxygen. BY E. L. HARPER. *Anal. Chem.*, **25,** 187 (1953).

A technique and the necessary apparatus for determining D. O. in 37 ml. of water is described. R. S. INGOLS

Sanitary Engineering Conference Held at South District Filtration Plant, City of Chicago on September 11, 1952. U.S. AEC Gov. Doc. No. Wash-129, Tech. Inf. Serv. Oak Ridge, Tenn.

The document consists of 25 papers (189 pages) summarizing the research and survey investigations pertaining to radioactive waste treatment and disposal conducted by several universities, the AEC or its contractors; the USGS, USPHS and the U.S. Weather Bureau. The subjects cover a broad field, including the diversity of problems, the effect of radioactive isotopes in treatment processes and tests, the removal of radioisotopes from water and wastes, methods and instrumentation for assaying radioactivity, and the meteorological programs. L. R. SETTER

Effect of Detergents on Sewage and Water Treatment. ANON. *Chem. Eng. News*, **31,** 1072 (1953).

This article gives basic information about synthetic detergents, as well as discussing the problems encountered in water and sewage plant operation from synthetic detergents. Because of the phosphates used in household cleaners, much greater algae growths may be expected in receiving streams and lakes than were found before phosphate use.

In some cases non-foaming synthetic detergents may still apparently cause foaming at a sewage treatment plant.

R. S. INGOLS

Determination of Oxygen Demand and B.O.D. by the Use of Oxygen. BY K. VIEHC. *Gesundh.-Ing.*, **74,** No. 7/8 (1953).

At 5-day B.O.D.'s above about 4 p.p.m. pure oxygen is usually negligibly inhibitory on the value of the B.O.D., but it does inhibit nitrification. Pure oxygen may thus be used for 24-hr. oxygen demands for undiluted river waters without necessitating complicated Sierp or Warburg equipment. 5-day B.O.D.'s require fewer and lower dilutions. PETER K. MUELLER

Water and Sewage Problems in Schleswig-Holstein. BY E. WEISE. *Gesundh.-Ing.*, **74,** 20 and 52 (1953).

Only about 50 per cent of the population are connected to centralized water systems. Hardly any sewage treatment plants exist. Typhus and paratyphus incidence was 2.44 and 1.4 per 10,000 population in 1950. Recommendations for public education, for organization, and for administration of water resources are cited. The author recommends a ground-water supply survey, central water supply, complete sewage treatment, utilization of digester gases, preparation of fertilizer from sludges, controlled sewage farming by means of spray irrigation, and utilization of wind power for plants wherever possible.

PETER K. MUELLER

Self-Purification and Permissible Sewage Load. BY W. MÜLLER. *Gesundh.-Ing.*, **74,** 15 (1953).

The principles of self-purification are thoroughly reviewed. The ratio of reaera-

tion (k_2) and oxidation (k_1) rates is approximately constant for most streams. Thus k_1 and k_2 are interdependent, so that $(B.O.D.)_s = f\ Dc = 1.25\ Dc$, where $(B.O.D.)_s$ is the permissible total B.O.D. of the stream, $f = k_2/k_1$, and Dc is the desired oxygen deficit. For streams support ing fish life the 5-day B.O.D. should not exceed 5.0 p.p.m. PETER K. MUELLER

Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water. Nat. Bur. of Stand. Handbook 52. Supt. of Doc., Washington 25, D.C. Price, $0.20 (1952).

Subcommittee 2 on Permissible Internal Dose of the National Committee on Radiation Protection, under the sponsorship of the National Bureau of Standards, has revised NBS Handbook 42 on the basis of new biological toxicological and radiochemical evidence. The provisional levels of permissible concentrations of unknown mixtures of radioisotopes in the air and water, exclusive of natural background, are 100 $\mu\mu$c. of alpha or beta-gamma per liter of water, 1 $\mu\mu$c. of beta-gamma per liter of air, and 0.005 $\mu\mu$c. of alpha per liter of air.

Tables are given for the permissible amount of specific isotopes in the body and the permissible concentration in air and water for continuous exposure and the factors used in arriving at "tolerance" values. For instance, the maximum permissible level (MPL) in water for Ra^{226} (alpha and beta emission) is 40 micromicrocuries per liter ($\mu\mu$c. per l.). The MPL in water for Sr^{90} and Y^{90} (beta emission) is 800 $\mu\mu$c. per l. Other listed isotopes are permitted in higher concentrations. L. R. SETTER

Theorie und Praxis des Abwasserlastplanes. (Theory and Practice of Sewage Loading Factors.) BY G. MÜLLER-NEUHAUS. Reprint from *Die Wasserwirtschaft* (1952).

This article describes the factors which affect the waste loading of streams, the attendant difficulties in measurement of these factors, and a method for estimating the allowable loading for streams. The Lippe River of the Emscher District of Germany is used as an example.

Although no new and startling methods and theories are presented, the factors are discussed in an interesting and complete manner. A series of loading diagrams, upon which is plotted distance along the stream *versus* the ratio of the existing loading to the computed allowable loading, were presented for the different stages of flow and stream temperatures. The computed values were checked by actual measurement. The diagrams show where and under which conditions of flow and temperature the ratio exceeds unity, the critical loading. It is interesting to note that the ratio for the River Lippe at 60 cu. m. per sec. flow and 8° C. remains below unity for its entire length, but under summer conditions of 7.7 cu. m. per sec. and 15 to 25° C. temperature, the ratio climbs above unity for most of the river length, and at points goes to as much as 2.6.

The author states that the principles and methods presented could be used with a minimum of stream and waste load data to form plans for streams, but cautions that much leeway must be used in drawing conclusions in such instances.

G. R. GRANTHAM

Zwei Neue Kläranlagen der Emschergenossenschaft. (Two New Clarification Plants of the Emscher District.) BY H. WIEGMANN AND G. MÜLLER-NEUHAUS. Reprinted from *Die Wasserwirtschaft* (1952).

The first two primary treatment plants of the seven planned for post-war new construction in the Emscher District are described. The principal post-war activity has been the reconstruction of the prewar system of 23 plants, of which only 10 were in operation in 1945 when 90 per cent of the sewage of the area flowed untreated into the Emscher and Rhein. In 1950, 75 per cent of the population and 85 per cent of industry were again connected to treatment plants. The seven new plants will bring the wastes from the entire population and all industry under treatment.

The larger of the two plants, Bernemundung, consists of two circular clarification basins 65 m. in diameter designed to provide primary treatment for about 410,000 persons. Depth varies from 1.8 m. at the edge to 3.65 m. at the center. The second plant, Schwelgern, consists of one clarifier 38 m. in diameter, 0.7 m. deep at the edge and 2.4 m. deep at the middle,

and designed for about 28,000 persons. Both plants have sludge scrapers, center sludge hoppers, and separate sludge treatment. The larger plant cost was 1,400,000 D.M.; the smaller, 500,000 D.M.

Of particular interest is the construction of the two plants, because both are placed on soil that may sink because of shifting earth due to old mine works. Instead of overflow weirs, which would require constant and considerable adjustment, vertical slots spaced around the tank wall were used. These discharge in proportion to the head on them, which varies depending upon the flow and the amount of additional storm water. Reinforced concrete walls and slabs designed to move are made water-proof by copper plates cast into the joints. The center works are provided with special foundations, the rim track for the scraper arm being made of pre-cast beams so placed as to be adjustable. The bottom slab of the Schwelgern plant is hyperbolic in shape to provide constant horizontal velocity of flow from the center to the rim. Special distributing slots reduce to a considerable extent the short-circuiting and increase the settling efficiency almost twofold.

G. R. GRANTHAM

The Law Relating to River Pollution Prevention. BY G. E. WALKER. *Jour. Inst. San. Eng.* (Gt. Brit.), **52**, 2, 105 (1953).

This is a review of the situation in Great Britain, bringing up to date a former paper in the *Journal* (July, 1944, p. 329). The subject matter is divided into two parts; namely, the common law position and the statutory prohibition of pollution. Since 1944, three main events have occurred—the passing of the River Boards Act in 1948, the publication of the Report of the Rivers Pollution Sub-Committee in 1949 (the so-called Hobday Report) on Prevention of River Pollution, and the coming into force of the Rivers (Prevention of Pollution) Act in 1951.

The common law position has not changed since 1944 in Great Britain. The author discusses the necessity for pollution prevention, with definitions, and summarizes the common law position, the statutory prevention of pollution, the Rivers Board Act of 1948; several Private Acts; and the Rivers (Prevention of Pollution) Act of 1951. By-laws may be passed prescribing standards for matters to be treated as poisonous, noxious, or polluting by reason of its temperature or its effect in discoloring a stream.

Storm waters are subject to the Act in the same way as other effluents. As yet, no standards have been formulated in general, although the recommendations of the Royal Commission on Sewage Disposal may be adopted where albuminoid ammonia exceeds 2 p.p.m., suspended solids exceed 30 p.p.m., and dissolved oxygen absorbed in five days (B.O.D. test) exceeds 20 p.p.m. Other tests are also applied.

The paper is of interest to those who wish to compare pollution law and control in Great Britain with the conditions in the United States. LANGDON PEARSE

BOOKS, REPORTS, AND PAMPHLETS

Second Annual Ohio Water Clinic. Ohio Chamber of Commerce, Columbus, Ohio. 21 pp., mimeo. (1953).

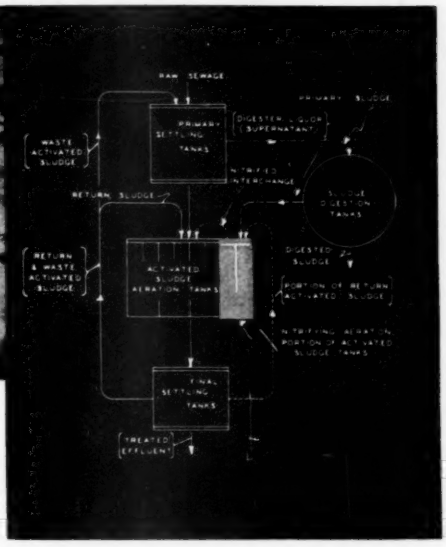
Abstracts of papers presented at the meeting, held February 19–20, 1953, in Columbus, Ohio, on the conference theme "Water Management."

Assaying Techniques for Radioisotopic Contaminants in Water Supplies. BY GORDON WHELER, JR., WARREN J. KAUFMAN, AND ROLF ELIASSEN. Sedgwick Lab. of San. Science, Mass. Inst. of Tech., Cambridge, Mass. (1952).

Effect of Beta Radiation upon Biochemical Oxidation of Polluted Waters. BY ROLF T. SKRINDE AND CLAIR N. SAWYER. Sedgwick Lab. of San. Science, Mass. Inst. of Tech., Cambridge, Mass. (1952).

Flow Metering—Technical Information Sheet 15-K-40w. Foxboro Co., Foxboro, Mass. (1953).

Contains 6 pages of practical information on flow metering, with tables, curves, and illustrative problems. The data should be extremely useful to consulting engineers, designers, and health department personnel concerned with preparing or checking treatment plant plans.



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Proceedings of Member Associations

MONTANA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 9th Annual Meeting of the Montana Sewage and Industrial Wastes Association was held in Kalispell, Mont., on April 23, 1953. A total of 53 registered for the meeting.

Papers were presented as follows:

"Fundamentals of Natural Purification in Streams," by John Wilson, Biologist, USPHS, Portland, Ore.

"Stream Gaging and Its Relation to Pollution Studies," by Allan Sollid, USGS, Kalispell, Mont.

"Sewage Lagoons," by A. W. Clarkson, Montana State Board of Health, Helena, Mont.

At the business meeting, F. F. Palmer, City Engineer, Forsyth, Mont., was nominated to receive the Federation's Arthur Sidney Bedell Award.

Officers elected for 1953–4 were as follows:

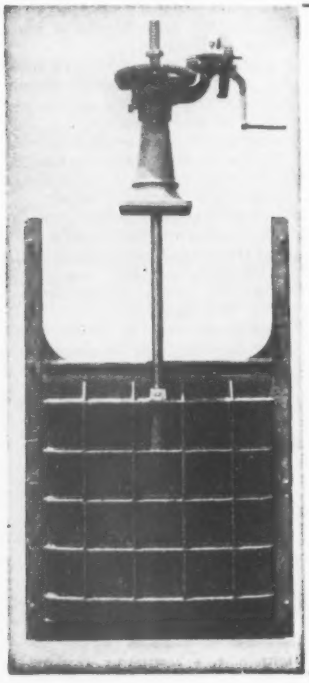
Chairman: C. King, Chinook.
Vice-Chairman: H. Owen, Billings.
FSIWA Director: H. Owen, Billings.
Secretary-Treasurer: H. W. Taylor, Helena.

HARVEY W. TAYLOR,
Secretary-Treasurer

ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION

The 16th Annual Meeting of the Rocky Mountain Sewage Works Association was held at the Frontier Hotel, Cheyenne, Wyo., September 15,

(*Continued on page 442a*)



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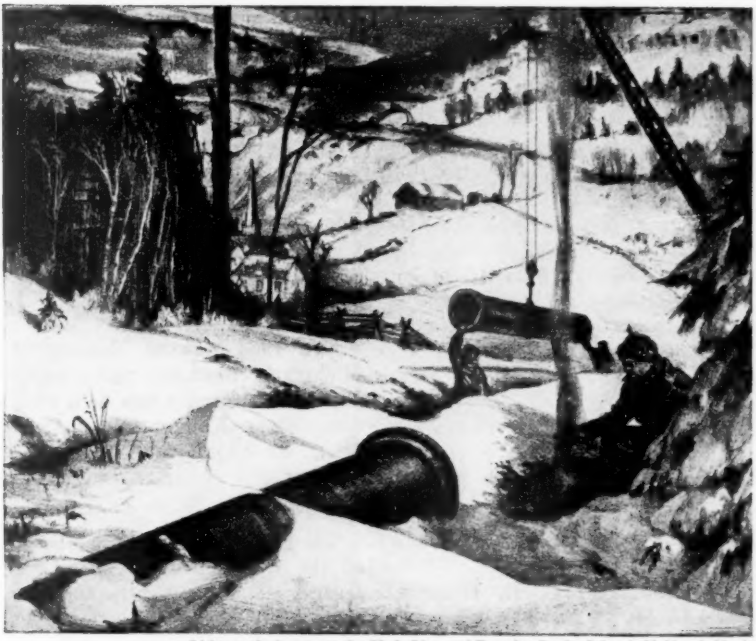

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1952. Registration totaled 52 members and guests.

A paper on "Stream Pollution Abatement," by W. N. Gahr, Director of Sanitation and Sanitary Engineering, Colorado State Board of Health, was discussed by L. O. Williams, Jr., and Charles G. Caldwell, his counterparts in the Wyoming and New Mexico State Boards of Health, respectively. This was followed by an "Operators' Round Table on Problems and Operation of Sewage Treatment Plants," led by Dana E. Kepner, Manufacturers' Representative, Denver, Colo.

At the Annual Business Luncheon, the following officers were elected to serve during 1952–53:

President: C. H. Coberly, Denver, Colo.
Vice-President: J. Frederick, Colorado Springs, Colo.
Secretary-Treasurer: C. E. Harness, Denver, Colo.

The meeting closed with an inspection trip to the Cheyenne sewage treatment plant, following a paper describing the new Cheyenne plant, by Ray Sherrard, Superintendent of Sewage Treatment, and Fred Koester, Sewage Plant Superintendent.

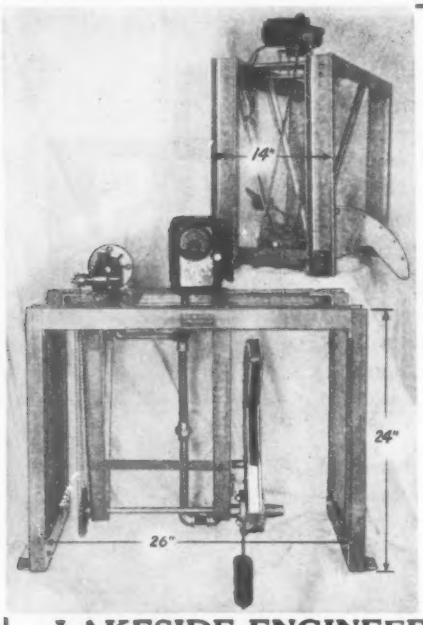
C. E. HARNESS,
Secretary-Treasurer

MICHIGAN SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 1953 Annual Meeting of the Michigan Sewage and Industrial Wastes Conference was held at Michigan State College, East Lansing, Mich., on September 21–23, 1953. A total of 235 registered for the meeting, including 30 ladies.

The following papers were presented at the technical sessions, as well as several elementary talks for new operators:

(*Continued on page 444a*)



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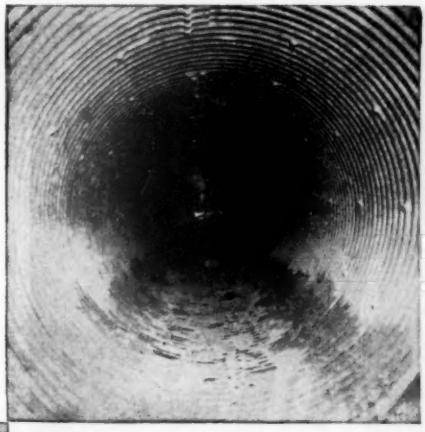

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"Public Relations from the Standpoint of the Sewage Works Operator," by W. H. Wisely, Executive Secretary, FSIWA.

"Effective Sewage Disposal through Integration of Sewage Collection and Treatment Facilities," by George Sandenburgh, City Engineer, and C. P. Witcher, Superintendent of Sewage Treatment, Ann Arbor.

"Effect of Plating Wastes on Trickling Filters," by C. F. Gurnham, Head, Dept. of Chemical Engineering, Michigan State College.

"Report on Chlorine Supplies," by L. F. Oeming, Chief Engineer, Michigan Water Resources Commission.

"Sewage Disposal Problems in Suburban Areas," by W. F. Shephard, Director, Division of Engineering, Michigan Department of Health, Lansing.

"Safety Practices in Sewage Treatment," by C. T. Mudgett, Superintendent, Muskegon.

"The Operator's Library," by M. S. Richmond, Sanitary Engineer, Michigan Department of Health.

"Industrial Waste Treatment at Trenton, Mich., Chrysler Plant," by Austin Beebe, Chrysler Corp.

"Development and Operation of a Chromic Acid Recovery System," by M. S. Morrison, Illinois Water Treatment Co., and Robert Brink, Standard Research Dept., Buick Motor Div., General Motors Corp.

"Waste Disposal by Return Wells," by J. Adinoff, Salvage Engineer, Parke-Davis and Co., and M. E. Austin.

"Disposal of Cannery Wastes by Spray Irrigation," by Walter Hicks, Michigan Fruit Canners, Inc., and Max Dietz, Research Dept., Gerber Products Co.

"Design and Operation of the Lansing Sewage Treatment Works," by S. D. Porter, Consulting Engineer, and George F. Wyllie, Superintendent.

Inspection trips were made to the

(*Continued on page 446a*)

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MARYLAND–DELAWARE WATER AND SEWERAGE ASSOCIATION

The 26th Annual Conference of the Maryland-Delaware Water and Sewerage Association, was held at the Commander Hotel, Ocean City, Md., on May 21–22, 1953. A total of 150 persons registered for the meeting.

The technical sessions featured the following papers:

"Abandoning Old and Starting New Water Filtration Plant," by Robert E. Greenshields, Springfield State Hospital.

"Cleaning Well Screens," by Louis R. Caplan, Calgon, Inc.

"Diatomaceous Earth Filters for Swimming Pools," by William H. Cary, Jr., Director, Bureau of Public Health Engineering, Washington, D. C.

"Characteristics of Poultry Packing Wastes," by A. Joel Kaplovsky, Supervising Engineer, Water Pollution Commission, Dover, Del.

"Sewage Pumping Stations on Water Supply Reservoirs," by William F. Neale, Whitman Requardt and Associates, Baltimore, Md.

"Storm-Water Inlets—Rainfall and Runoff," by Bernard F. Suwall, Principal Associate Engineer, Baltimore, Md.

"Regulations to Control Environmental Sanitation," by Robert M. Brown, State Department of Health, Baltimore, Md.

"Authority Law Operation for Water Supply and Sewerage," by Clark Gardner, Gardner and Sterling, Salisbury, Md.

"Design and Operation of the Salisbury Incinerator," by Percy Sterling, Gardner and Sterling, and Philip C. Cooper, City Engineer, Salisbury, Md.

Officers elected to serve during 1953–54 were:

President: R. H. Ritter, Baltimore, Md.
1st Vice-President: E. F. Donaldson, Annapolis, Md.
2nd Vice-President: R. L. Nichols, Fort Meade, Md.
Secretary-Treasurer: W. M. Bingley, Baltimore, Md.

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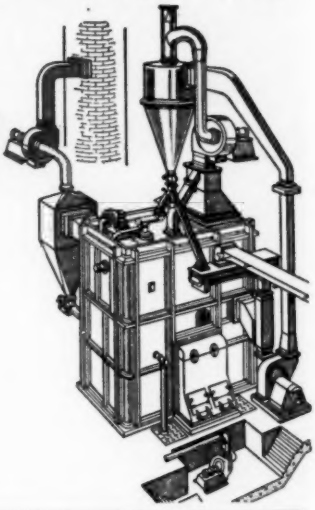

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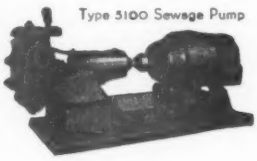
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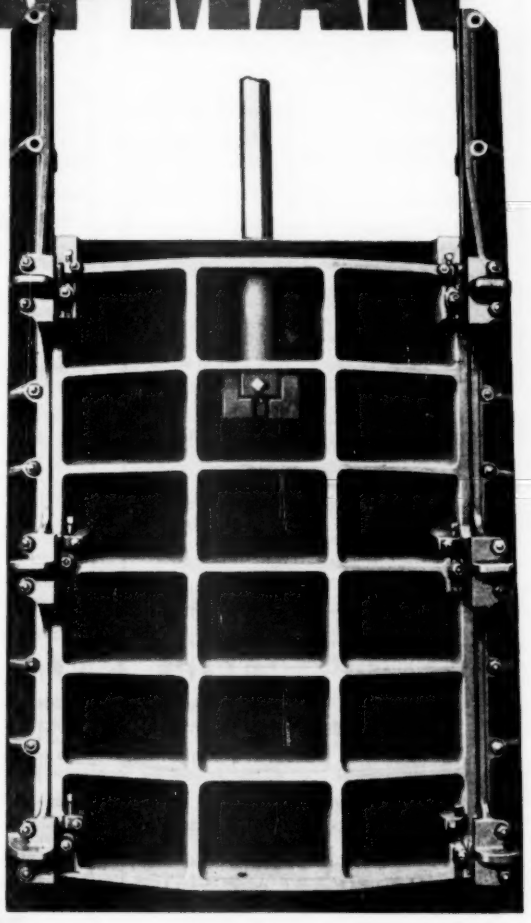

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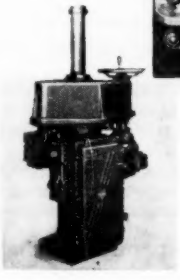

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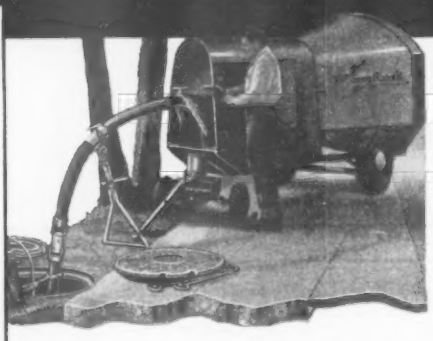

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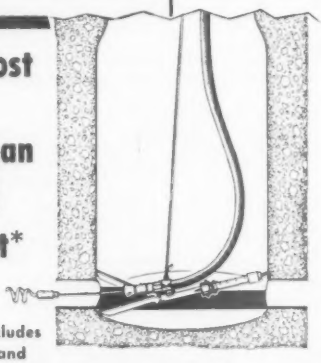

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